The Morphodynamics of a Sand and Gravel Barrier, Southern Hawke Bay, North Island, New Zealand

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ABSTRACT.

Little is known about mixed sand and gravel beaches over an extended time period (seasons) or for specific wave energy events. This thesis addresses this problem by analysis of the gravel textures (sizes and forms) and the cross-shore transverse profiles for the southern Hawke Bay barrier, which possesses a well defined wave energy gradient and gravel supply and sink along some 16 km of coastline.

Analysis of beach profile surveys show that the profile parameters (beach height, width, sediment volume and 'Profile Index') do not have normal distributions and can be highly skewed. The profile index parameter indicates the beachfaces are restricted to concave up and linear shapes. Consecutive cross-shore profile surveys demonstrate the beachface has two response 'types' to high seas. Firstly, the beachface 'hinges' about MSL, shown by alternating maximum and minimum beach heights at the High and Low Water positions. So, when the High Water ridge is at a maximum height the Low Water platform is a minimum, and vise versa. The second response type occurs when an accretional High Water ridge welds onto an antecedent High Water ridge. At a seasonal time scale the updrift sites have an ongoing negative change of sediment volume (erosional). In addition, the profile index indicates a general evolution from concave up to a more linear profile shape (increasingly 'reflective'). These results suggest that as the profile shape evolves it does not affect the overall sediment loss (erosion).

Over a season the winter gravel sizes are coarser, better sorted and coarse skewed compared to the summer season population. Generally, the sink gravels at the high-energy Marine Parade site are finer, more poorly sorted and more coarsely skewed than those at the low wave energy Clifton gravel supply. Indeed, at the sink the high water moderate wave energy (breaking wave height $H_b > 1.0$ m; breaking wave steepness $B_s > 0.03$) gravels depositional at the High Water ridge show increasing coarse skewness. Coarser clasts become more bladed in the littoral drift, but on average, the percentages of spheres do not increase in the direction of littoral drift. Towards the high-energy environment, the oblate prolate index becomes more negative (increasingly discoidal), whilst the maximum projection sphericity has a very small decrease. In general, the gravel textures show greater variation at each site and at the intersample intervals than at the seasonal sampling interval.

During a moderate wave energy event the beachface slopes flatten at the supply sites (coarse grain) and steepen at the sink sites (fine grain) as the breaking wave steepness increases from 0.019 to 0.035, i.e. from "plunging" towards "spilling" waves. At the Te Awanga Hall site during both the moderate and high-energy wave events, the beachfaces flatten as the breaking wave steepness increases. Gravels transport and deposit as overwash at breaking wave steepness > 0.0451 and as overtop deposition at breaking wave steepness 0.0279. These overwash and overtop depositional gravels have coarser sizes, better sorting and more positive (fine) skewness to landward. The initial gravel forms transported landward are rodic, not discoidal.

Analysis of the gravels in the regional 'geological column' (Pliocene to Pleistocene) adjacent to and distal from the Ruahine Ranges gravel source, demonstrate that as the gravels become younger the clast forms become increasingly discoid. Along the contemporary Tukituki River that links the source to the coastal supply, the disc form dominates. These findings suggest that discoidal clast forms on the beachface are not solely a result of abrasional swash process, but are predetermined perhaps by primary tectonic stress.

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TABLE OF CONTENTS

Page

Abstract i
Acknowledgements ii
Table of Contents iii
List of Figures ix
List of Tables xiii

Chapter 1: Introduction

1.1 The Importance of MSG Beaches to Hawkes Bay 1
1.2 Previous Investigations of the Hawke Bay Barrier 3
1.3 Definition of Mixed Sand and Gravel Beaches 5
1.4 Aims of the Research 6
1.5 Distribution of MSG Beaches in New Zealand and the World 8
1.6 Some Wider Topics 9

Chapter 2: Physical Background to the Southern Hawke Bay

2.1 Introduction 13
2.2 The Physical Setting of the Hawke Bay Coastal Environment 13
2.3 Primary Factors of the Hawke Bay Barrier Evolution (Geology, Sea Level, Bathymetry and Atmospheric Climate 13
2.4 Hydrodynamic Factors Affecting the Southern Hawke Bay Barrier 20
2.5 Nearshore Currents in Hawke Bay 26
2.6 Conclusions 30

Chapter 3: The Physical Characteristics of the Mixed Sand and Gravel Barrier Field Sites

3.1 Introduction 33
3.2 Field Sites 34
3.3 Conclusions 41

Chapter 4: The Field Area – A History of Coastal Change and Human Responses

4.1 Introduction 42

4.2 Historical Records 42

4.3 Summary and Discussion of the Historical Records and Coastal Evolution Introduction 48

4.4 History of Coastal Development and Defenses 49

4.5 History of Erosion and Accretion in Southern Hawke Bay 54

4.6 Summary of Coastal Development, Defenses, Erosion, and Accretion in Southern Hawke Bay 56

Chapter 5: The Beachface Morphology and Its Response to Variations in Wave Characteristics

5.1 Introduction 57

5.2 The Hawke Bay MSG Barrier Beachface Morphology 57

5.3 Morphodynamics and Processes 63

5.4 The Morphological and Hydrodynamic Relationships Observed at the Te Awanga Beachface 65

5.5 Discussion 73

5.6 Conclusions 75

Chapter 6: The Morphodynamic Parameters Applied to the Hawke Bay Beachface

6.1 Introduction 77

6.2 The Breaking Wave Morphodynamic Parameters-Previous Studies 77

6.3 Profiles. Defining the MSG Beach Profile 80

6.4 The Quantitative Subaerial Beachface Analysis 82

6.5 Summary and Conclusions 84

Chapter 7: Beach Surveys, Cross-shore Transverse Profiles

7.1 Introduction 85

7.2 Literature Review 85

7.3 Profile Morphology. Examples of the Temporal Configurations 86

7.4 The Profile Relationships: The Shape and Beachface Parameters 89

7.5 Beachface Relationships of Sedimentary Volume and Profile Index 93

7.6 Profile Morphodynamics and Cross-shore Topographic Changes 98

7.7 The Morphodynamic Relationships: Sediment Volume Change (dQ), Profile Index (PI), Breaking Wave Steepness (B_s), Surf Scaling Parameter (ε) and Iribarren Number (ξ). 103

7.8 Conclusions 113

Chapter 8: The Sedimentary Characteristics of Mixed Sand and Gravel Beachfaces

8.1 Introduction 116

8.2 Clast Textural Analysis 116

8.3 Sediment Textural Patterns 116

8.4 Hawke Bay Clast-Conceptual Models 124

8.5 Summary and Conclusions 130

Chapter 9: Lower Beachface Gravel Size Paramaters

9.1 Introduction 132

9.2 Sampling 132

9.3 Textural Parameter Methodology 132

9.4 Results 133

9.5 The Intersample Trends (Fluctuations within Sampling Period) 138

9.6 HB Gravel Sizes and the Wave Energy Gradient, the Gravel Supply and Sink 139

9.7 Discussion of the Hawke Bay Lower Beachface Gravel Textural Parameters 140

9.8 Conclusions 142

Chapter 10: Beachface Response During a "Moderate Seas" Event

10.1 Introduction 145

10.2 Results 146

10.3 Summary, Gravel Sizes and the Morphodynamic Responses to a Moderate Wave Energy Event 156

10.4 Conclusions 159

Chapter 11: Beachface Response to a "High Seas" Event

11.1 Introduction 160

11.2 Results 162

11.3 Discussion Grain Size Parameters 166

11.4 Summary, The Morphodynamic Responses to a High Wave Energy Event 168

11.5 Conclusions 168

Chapter 12: The Responses of the Combined Moderate and High Wave Events at Te Awanga Hall

12.1 Introduction 170

12.2 Results and Discussion 170

12.3 Conclusions 171

Chapter 13: The Clast Forms at the Southern Hawke Bay Beachface

13.1 Introduction 173

13.2 Results 173

13.3 Longshore Temporal Clast Form Changes 178

13.4 Results 179

13.5 Oblate Prolate Index and Maximum Projection Sphericity of Hawke Bay Clasts 182

13.6 Discussion of Clast Forms and Sizes 185

13.7 Cross-shore Form Changes with Wave Energy Events 187

13.8 The Combined Form Parameters, the Moderate and the High Energy Events at Te Awanga Hall 190

13.9 Summary and Conclusions 193

Chapter 14: The Source and Supply of Terrestrial Gravels to the Southern Hawke Bay Beach

14.1 Introduction 196

14.2 Source and Supply of the Contemporary Hawke Bay Gravels 196

14.3 Inland Source Gravels (Near the Ranges) 197

14.4 Results (the Inland Clasts) 198

14.5 Summary, the Inland Source Gravels 200

14.6 Contemporary River Clasts (the Tukituki River valley) the Source-Supply link 201

14.7 Contemporary Supply Gravels at the Coast 203

14.8 Summary of Supply (Cape Kidnappers and Tukituki River) Clast Parameters 203

14.9 Discussion, Clast Supply Parameters 205

14.10 Conclusions 205

Chapter 15: Conclusions

15.1 The Major Findings 207

15.2 Future Research 210

15.3 Coastal Management 210

15.4 Ubiquitous Conclusion 211

References 212

Appendix 1. The Hawke Bay Coastal Geology 227

Appendix 2. Sea Level and the Genesis and Evolution of the Hawke Bay Barrier 249

Appendix 2.1 Fauna Identification 263

Appendix 3. Historical Bathymetry Charts of Hawke Bay 265

Appendix 4. Sampling, Bench Mark Positions, Gravel Sizes, ZINGG classification, 266

Appendix 5. Verbal Description for the Hawke Bay Gravel Size Skewness and Sorting Parameters. 279

Appendix 6. Wave and Tide Summary for Gravel Sampling Period, and Textural Gravel Size Parameters Summary 280

Appendix 7. Extended Time Gravel Forms, Example Form Summary 284

Appendix 8. Cross-shore Transverse Profile, Data and Datum 291

Appendix 9. Beachface Indicators (histograms) 298

Appendix 10. Bivariate Plots of Sediment Volume Change and the Profile Index 302

Appendix 11. Sediment Volume Change and Profile Index Time Series 305

Appendix 12. Accretion and Erosion Profiles 309

Data Files (CD)

LIST OF FIGURES

Figure	Contents	Page Number
1.1	Location map of geographical place names, Hawkes Bay, North Island, New Zealand.	2
1.2	View of Scinde Island towards Westshore. All the low area was uplifted 1.8 m in the 1931 Napier earthquake.	3
1.3	View towards Westshore, the beachface Hardings Road. A boulder lag beach in the lee of Napier Port breakwater.	4
1.4	View towards Napier. The Tukituki River inlet spit. Overwash sediments on the downdrift side of the Haumoana groyne.	5
1.5	View towards Cape Kidnappers from Te Awanga (K2). The beachface is erosional with rail-iron and tyre 'seawall' and recent soil spoil 'protection'.	9
1.6	View south, Marine Parade, Napier. Note upper beachface finer gravels compared to those at Te Awanga (K2).	10
1.7	View south towards Napier and Scinde Island from Westshore. Re-nourishment berm with material from Marine Parade. An erosional beach with exposed storm drain cupola.	12
2.1	Location of Hawke Bay, North Island, New Zealand and the location of the field area in southern Hawke Bay.	14
2.2.	Hawke Bay Holocene relative (to modern Mean Sea Level at 0 m) sea level curve.	15
2.3	The southern Hawke Bay bathymetry.	16
2.4	Scatter plot of the local atmospheric pressure and wave steepness, January 2000.	18
2.5	Frequency of storm events reported in southern Hawke Bay over the previous 200 y.	20
2.6	Tidal and local datum transposed onto a transverse profile.	21
2.7	Hawke Bay continental slope WAM model hindcast statistics and frequencies.	23
2.8	Te Awanga Hall, observed breaking wave height statistics and frequency.	25
2.9	Te Awanga Hall, observed breaking wave period statistics and frequency.	25
2.10	Te Awanga Hall, observed breaking wave steepness (B_s) statistics and frequency.	26
3.1	"Evolution typology" for gravel barriers on a paraglacial coast undergoing erosion.	33
3.2.	Clifton, beachface bedrock.	35
3.3	Clifton, overstepped transgressive barrier.	36
3.4	Clifton sample site.	37
3.5	Te Awanga Hall sample site.	38
3.6	Te Awanga K2 sample site.	39
3.7	Haumoana sample site.	40
3.8	Marine Parade sample site..	41

4.1 The Ahuriri lagoon in 1865. 43
4.2. Marine Parade 1864. Barrier spit. 44
4.3. Ahuriri in 1965.. 45
4.4. Te Awanga 1936. Vertical air photograph. 47
4.5. Te Awanga 1950. Vertical air photograph. 48
4.7 Location map of historical coastal defenses and sampling site 50
4.8. Haumoana, late 1960's defense. 52
4.9 Marine Parade after the 1931 earthquake. 53
4.10 Southern Hawke Bay relative shoreline change between 1936 and 1972. 55

5.1 The Hawke Bay contemporary barrier beachface morphology component. 57
5.2 An idealised lower beachface morphology component. 58
5.3 An idealised upper beachface morphology component. 60
5.4 Ideal planform morphology, the range from high energy 'winter' and low energy 'summer'. 63
5.5 Westshore Napier the beachface has three cusp morphologies, cross-shore, attached and detached. 64
5.6 Te Awanga Hall. Tier of reworked high water ridges. 66
5.7 Te Awanga Hall. Terrace cut scarp at the high water ridge. 67
5.8 Te Awanga Hall. Inshore breaking wave types. 68
5.9 Te Awanga Hall. Proto cusp formation. 69
5.10 Te Awanga Hall. Gravels depositing as overwash and overtop sedimentation. 72
5.11 Te Awanga Hall. High water ridge sedimentation and topography. 73

6.1 Model for beachface profile type classification. 83

7.1 Te Awanga Hall, seasonal transverse profiles from October 1998 to March 1999. The beachface responses. 86
7.2 Clifton. Isopleths at three select and fixed cross-shore distances, the beachface crest, the high water ridge, and the mean sea level (MSL) from May 1998 to August 2000. 88
7.3 Clifton. Frequency histograms of the active beachface morphodynamic parameters height, width, volume and reflectivity index (June 1998 to May 2001). 91
7.4. Clifton (supply, erosive) and Marine Parade (sink, depositional). Bivariate plot of intersample sediment volume change (dQ) and the profile index (PI) (June 1998 to May 2001). 94
7.5 Te Awanga K2. Changes of sediment volume (inter survey volume changes dQ) and beachface profile index (PI) as time series, June 1998 to May 2001. 96

7.6 Example cross-shore morphodynamics for two sample sites, Clifton and Marine Parade. The detrended transverse profiles over an equinox season. 100
7.7 Clifton. Detrended first vernal, first four profiles, example of the morphodynamic oscillations at the storm and high water ridges. 101

7.8. The general topographic envelope describing the morphodynamic changes of the Hawke Bay transverse profiles. 103
7.9 Te Awanga Hall. Bivariate plot of breaking wave steepness (B_s) and the intersample change of sediment volume (dQ). 104
7.10 Te Awanga Hall. Bivariate plot of breaking wave steepness (B_s) and the profile index (PI). 105
7.11 Te Awanga Hall. Surf scaling parameter (ε). Bivariate plot of beachface morphodynamics and the wave energetics. 106
7.12 Te Awanga Hall. Iribarren number (ξ). Bivariate plot of beachface morphodynamics, beachface slope (b) and the breaking wave steepness (B_s). 107
7.13 Te Awanga Hall. Temporal relationships of inter survey change of sediment volume (dQ); the profile shape index (PI) and wave steepness (B_s). Summer to Winter 2001. 109
7.14 Te Awanga Hall. Temporal relationships of the surf scaling parameter (ε). Summer to Winter 2001. 110
7.15 Te Awanga Hall. Temporal relationships of the Iribarren number (ε). Summer to Winter 2001. 111

8.1 The Hawke Bay barrier clast source and supplies. 126
8.2 Folger's Lake upper Tukituki River-Ruahini Ranges gravel supply and source. 127
8.3 Cape Kidnappers gravel supply. 127
8.4 The alongshore clast form changes (expected for reflective type beaches). 129
8.5 Cross-shore beachface clast changes (expected). 130

9.1 Mean grain size (Phi) variation from September 1997 to December 1997. 134
9.2 Sorting (Phi) variation from September 1997 to December 1997.. 135
9.3 Skewness variations from September 1997 to December 1997. 136

10.1 Te Awanga Hall incident inshore breaking wave characteristics and beachface morphodynamics, 26 September 2000, moderate wave energy erosion event. 146
10.2 Clifton, gravel sampling site for erosion event, 28 September 2000.. 147
10.3 Te Awanga Hall, gravel sampling site for 'erosion' event, 28 September 2000. 148
10.4 Wave parameters over a moderate wave energy event. 149
10.5 Marine Parade, gravel sampling site for 'erosion' event, 28 September 2000. 150
10.6 Gravel supply transverse profiles for erosive event (Clifton and Te Awanga Hall). 151
10.7 Gravel sink transverse profiles for erosive event (Marine Parade). 152
10.8 High and low water gravel size parameters at sample sites, erosional. 154

11.1 Te Awanga Hall sediment overwash deposition and High Water ridge morphology 3 June 2000. High wave energy deposition sampling conditions.. 161
11.2 Te Awanga Hall 6 June 2000 gravel samples post high wave energy event. 162

11.3 High wave energy event wave parameters. 163
11.4 Te Awanga Hall transverse profiles for high water ridge accretion event, June 2000. 164
11.5 Te Awanga Hall gravel size parameters for an accretional high water ridge, June 2000. 166
12.1 Te Awanga Hall combined moderate and high wave energy morphodynamics bivariate plot of beachface slope and breaking wave steepness. 170

13.1. The bladed clast forms over sampling period September 1997 to December 1997. 174
13.2. The disc clast forms over sampling period September 1997 to 12 December 1997.. 175
13.3. The rod clast forms over sampling period September 1997 to December 1997. 176
13.4. The spherical clast forms over sampling period September 1997 to December 1997. 177
13.5. The average longshore clast forms (ZINGG) blades, discs, rods and spheres. 179
13.6. Clast form and size relative abundances at Clifton (a supply) and Marine Parade (a sink)..181
13.7. Oblate-prolate index forms over sampling period September 1997 to December 1997. 183
13.8. Maximum projection sphericity forms over sampling period September 1997 to December 1997. 184
13.9 Te Awanga Hall. Gravel form parameters for an accretional event at a high water ridge. 191

14.1 Diagram indicating the sampling concept to model gravel form changes. Stratigraphic, modern coast, and the modern river link from Ranges to coast. 198
14.2 Clifton terrace cut beachface strata by sorting. 205

LIST OF TABLES

Table	Contents	Page number
2.1	Summary of southern Hawke Bay wave parameters.	31
7.1.	The minimum, maximum and average parameter values of the southern Hawke Bay active beachface crest height (H_c), beach width (S), sediment volume (Q) and profile index (PI).	92
7.2.	Semi-quantitative morphodynamic classification for intersample sediment volume change (dQ) and beach profile index (PI).	95
7.3.	Long trend drift of parameters of intersample volume changes (dQ) and profile index (PI). (Least squares regression gradient coefficients).	97
13.1	The relationships of clast form OPI and MPS to the alongshore wave energy gradient.	184
13.2	High and low water gravel form parameters (OPI and MPS) in a moderate high seas event (late September 2000).	189
13.3.	The relative changes of ZINGG (1935) clast forms over a springs equinox.	193
13.4.	The relative changes of the oblate-prolate index (OPI) and maximum projection sphericity (MPS) clast form parameters over a springs equinox.	194
14.1a	The ZINGG forms (%) for selected Pliocene-Pleistocene stratigraphic clasts.	199
14.1b	Summary of the OPI and the MPS for the stratigraphic clasts.	199
14.2a	The ZINGG forms (%) for the Tukituki River greywacke clasts supply.	200
14.2b	Summary of the OPI and MPS parameters for the Tukituki River gravel supply.	201
14.3a	The (ZINGG) clast forms for the Cape Kidnappers supply.	201
14.3b	Cape Kidnappers supply gravels, OPI and MPS.	202

14.3c Contemporary Hawke Bay barrier supply gravels, mean grain size (Phi), sorting (Phi), and skewness. 202

14.4 The average supply clast form parameters for the lower Tukituki River and the Cape Kidnappers cliffs. 203

CHAPTER 1 INTRODUCTION.

1.1 The Importance of Mixed Sand Gravel Beaches to Hawkes Bay[1].

Hawkes Bay is located on the most tectonically active region of New Zealand (HULL, 1990). Indeed, the 1931 Napier earthquake uplifted the Ahuriri lagoon some +1.8 m above Mean Sea Level (MSL) (HULL, 1990), from which Hawkes Bay gained large areas of fertile coastal plain. The Late Holocene environment of the southern Hawkes Bay (HB) was coastal lakes and wetlands (KINGMA, 1962), and since the Mid-Late Holocene, a barrier has existed separating extensive river fed wetlands from the ocean (GIBB, 1973).

The most conspicuous coastal morphological feature of the southern HB coastline from the port of Napier to Clifton is the mixed sand and gravel (MSG) barrier. This barrier beach is the prime focus of this thesis. The barrier is "transgressive" in the sense of migrating landward (WHITE and HEALY, 2000), and illustrates characteristics of erosional, accretional, or positional stability at various alongshore sectors (GIBB, 1973; SMITH, 1984).

Hawkes Bay, (Figure 1.1) like many other coastal environments about New Zealand, has witnessed a recent escalation of urbanisation and degradation of the coastal environment bordering the Hawke Bay. There is an associated proliferation of plans and strategies all with incumbent and escalating administrative costs. For all this there is at best small gain of insight into the physical nature of the coastal environments in question. This study of the southern HB morphodynamics is a step to reverse this temerity engendered by myopic speculation. The true value of the southern Hawke Bay barrier, even on a simplistic economic plane has not yet been realised or estimated. The HB MSG barrier represents a best protection for the socio-economic infrastructure contained across the Heretaunga Plain. This barrier is also an extremely valuable resource for scientific investigation that is easily accessible since many researched MSG barriers are in remote and inhospitable regions.

Human habitation has changed the Hawke Bay gravel barrier morphology. For example GIBB (1996) reports that the Ahuriri Lagoon inlet changed to, and was maintained at, its present location by pre-European Maori. With the arrival of the Europeans and commercial industry the Ahuriri inlet underwent further modification for navigation (O'CALLAGHAN, 1986). However, more widespread and extensive modifications of the barrier took place over this early period. For example, excavation of unrecorded quantities of shingle took place from around Scinde Island and from the Tukituki River inlet (pers. comm., Gordon Bambry) for land reclamation works and building an agrarian based industry. Indeed, the mining of beach MSG sediments continues at Awatoto for 'the building industry in conjunction with ad hoc local government 'requirements' for 'protection', for example, the renourishment of Westshore (Figure 1.7) and the stop bank on the Maraetotora River in Te Awanga.

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[i] Hawkes Bay is the regional designation for the provincial (terrestrial) part, whilst the Hawke Bay is the marine embayment north of Cape Kidnappers.

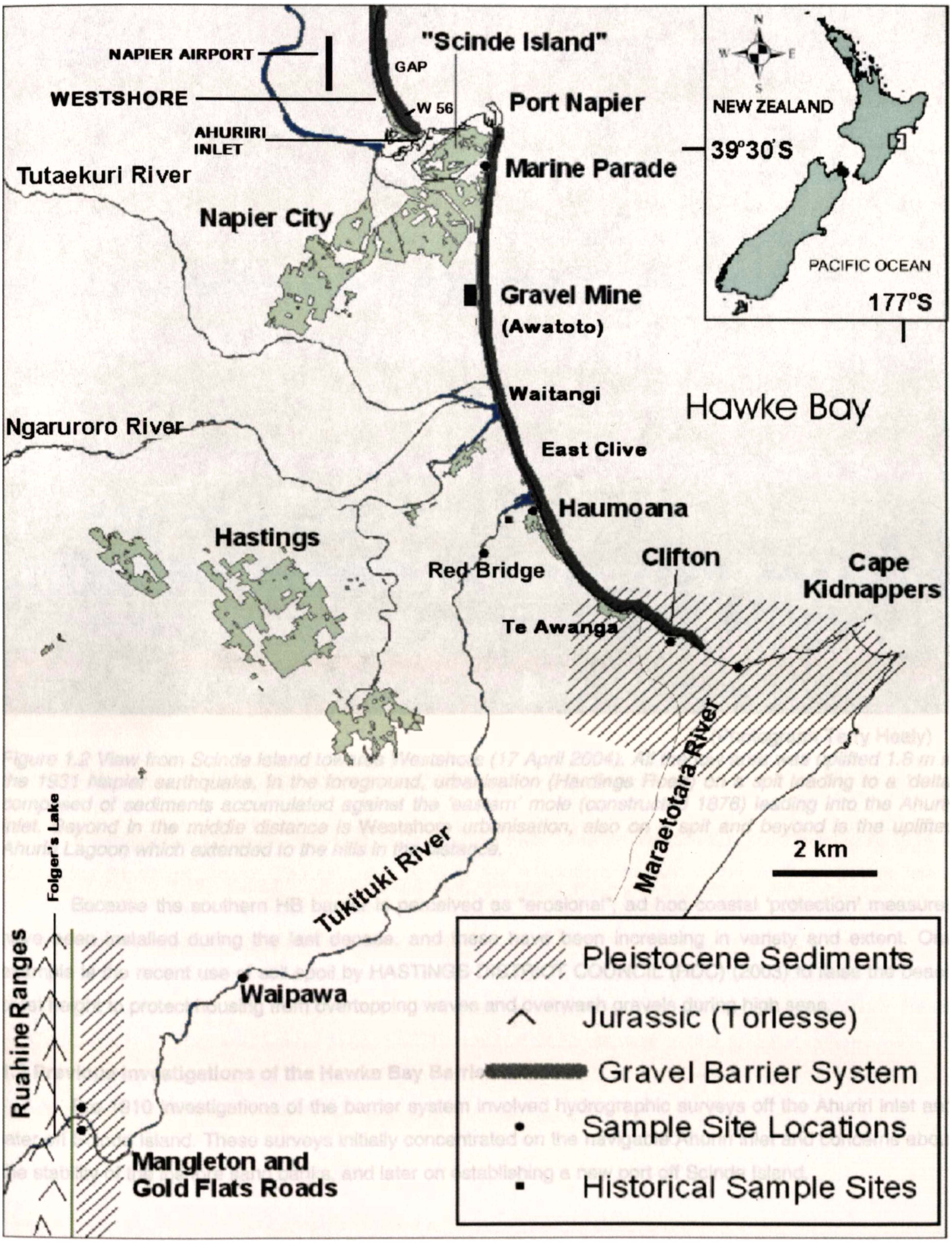


Figure 1.1 Locations (diagrammatic) of geographical place names, Hawkes Bay, North Island.

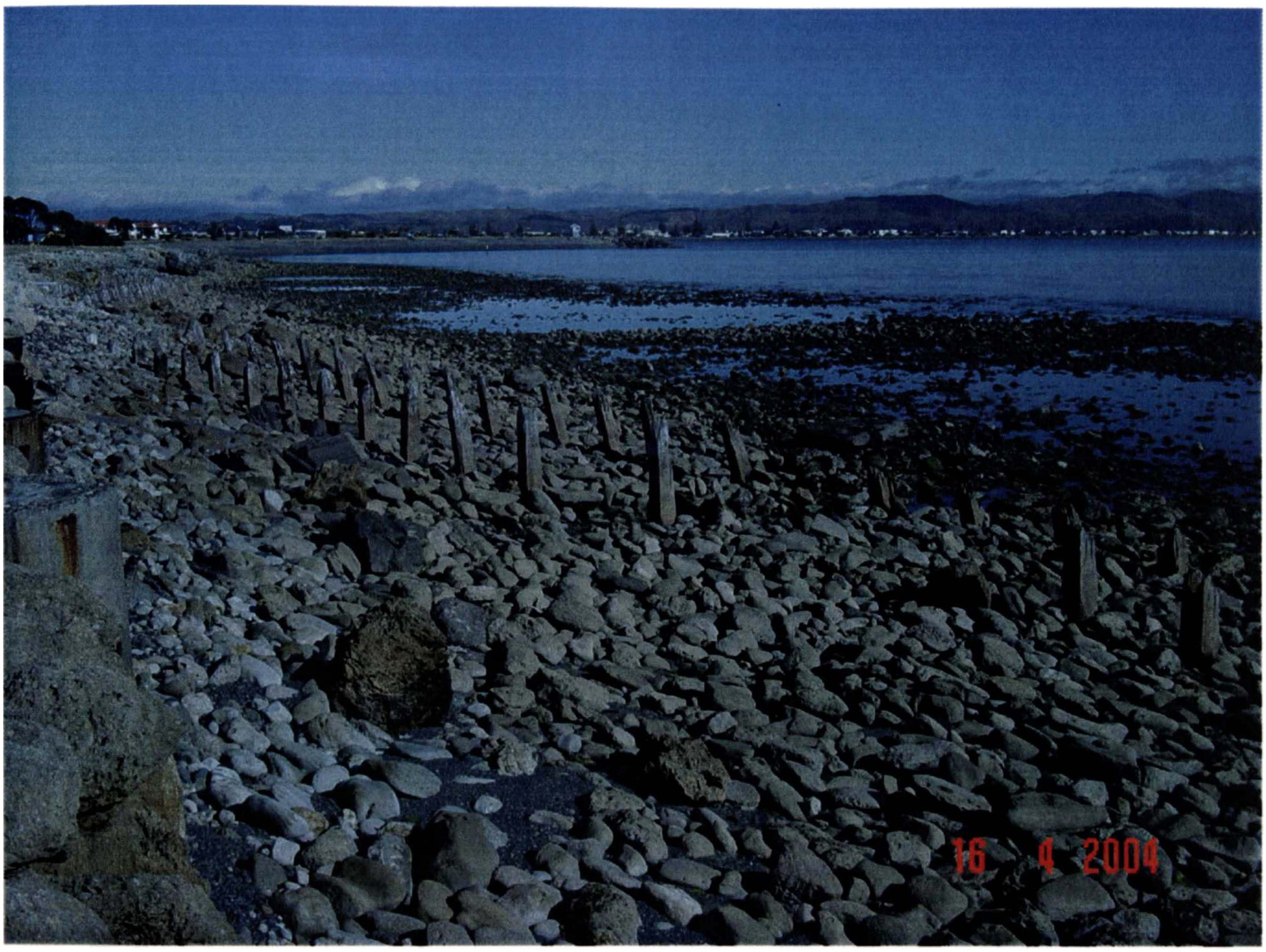
(Photograph Terry Healy)

Figure 1.2 View from Scinde Island towards Westshore (17 April 2004). All the low area was uplifted 1.8 m in the 1931 Napier earthquake. In the foreground, urbanisation (Hardings Road) on a spit leading to a 'delta' composed of sediments accumulated against the 'eastern' mole (constructed 1876) leading into the Ahuriri inlet. Beyond in the middle distance is Westshore *urbanisation, also on a spit and beyond is the uplifted Ahuriri Lagoon which extended to the hills in the distance.*

Because the southern HB barrier is perceived as "erosional", ad hoc coastal 'protection' measures have been installed during the last decade, and these have been increasing in variety and extent. One example is the recent use of soil spoil by HASTINGS DISTRICT COUNCIL (HDC) (2003) to raise the beach crest height to protect housing from overtopping waves and overwash gravels during high seas.

1.2 Previous Investigations of the Hawke Bay Barrier.

Pre 1910 investigations of the barrier system involved hydrographic surveys off the Ahuriri inlet and later off Scinde Island. These surveys initially concentrated on the navigable Ahuriri inlet and concerns about the stability of the inshore sand banks, and later on establishing a new port off Scinde Island.



(Photograph Terry Healy)

Figure 1.3 View towards Westshore (17 April 2004) clearly showing the beachface at Hardings Road, Napier. The beachface is a boulder lag beach in the lee of Napier Port breakwater.

Investigations between 1910 and 1950 involved transverse profile surveys, commencing in 1914 at East Clive (Hastings District Council), and 1916 at the Westshore barrier to the north of Scinde Island (HAWKES BAY REGIONAL COUNCIL). MARSHALL (1928, 1929) undertook the first scientific research on the beachface gravels, focusing on the clast abrasion.

Since 1970 there have been a proliferation of reports on coastal erosion, both to the south of Scinde Island (GIBB, 1973; SMITH, 1984), and to the north of Scinde Island at Napier's Westshore Beach (O'CALLAGHAN, 1986; WILLIAMS, 1986; SMITH, 1993). Recent studies on the physical nature of the HB barrier include the origin of the MSG beach gravels (WHITE, 1988) and a re-examination of the beachface gravel abrasion (HEMMINGSEN, 2001).

(Photograph Terry Healy)

Figure 1.4 View towards Napier (17 April 2004). The Tukituki River inlet spit. Overwash sediments on the downdrift side of the Haumoana groyne (built late February to March 1999). This is an example of an overstepping spit (single ridge roll-over) sector of the transgressive barrier

Scientific investigations on the Hawke Bay seabed sediments, include both regional (PANTIN, 1966; LEWIS, 1973) and inshore (HUME, et al., 1989); on the tectonic tilting (LEWIS, 1971); and on shallow inshore sediment transport numerical modeling (BLACK and VINCENT, 2001).

Industrialisation and city growth necessitated the construction of sewage ocean outfalls which in turn required pre-construction investigations of nearshore water circulation (RIDGWAY, 1962) and seabed sediments (CARTER, 1974).

1.3 Definition of Mixed Sand and Gravel Beaches.

Mixed sand and gravel (MSG) beaches are characterised texturally by sands and gravels (KIRK, 1980) in about equal proportions (COATES and MASON, 1998) that are intermixed throughout (JENNINGS and SHULMEISTER, 2002). Generally, there is sediment size segregation both across the and along the beach (CARR, et al., 1970) with gravely upper beach crests and ridges, and lower beach - foreshore sandy textures (KING, 1959). Most MSG beaches are reflective to incident wave energy (WRIGHT, et al., 1979) and can occur on exposed and indented coasts (HUGHES and COWELL, 1987).

1.4 Aims of the Research.

To date little research has been undertaken in the Hawke Bay gravel barrier systems, and yet as noted above, they are coming under increasing development pressure from a number of activities including coastal subdivision, mining, conservation needs and tourism. The primary aim of this thesis is to undertake investigation of the mixed sand and gravel beachface, including variations in time, of the southern Hawke Bay barrier from Clifton to the Port of Napier. The research focuses on two aspects, viz.,

(i) the gravel textural characteristics of the source, supply and sink zones, and
(ii) the beachface morphological and morphodynamic characteristics.

Accordingly, the major objectives of the research are to investigate

1. The beachface transect morphology and its variation in response to varying wave energy, seasonal effects and episodic wave effects.
2. The beachface gravel textural characteristics and the seasonal and 'event' effects;
3. The beachface gravel forms and their variation from source to sink, and
4. The clast form characteristics of the source and supply gravels.

There are a number of reasons that make this barrier system urgent to research:

- the barrier possesses a well defined gravel supply and sink;
- a lower beachface with a consistent gravel population;
- a distinctive source of greywacke gravel from the hinterland axial Ranges;
- gravel composition is predominantly a hard greywacke, so that abrasion processes should be uniform.
- the barrier has evidence of evolution ranging from initiation through establishment to breakdown;
- an embayment coast dominated by refracted swell waves (most accounts are for exposed coasts);
- longshore wave energy gradient occurs along some 16 km of coast;
- a well defined wave breaker line that is invariably at the lower beachface step;
- an active swash zone with a micro-tidal range of activity under normal conditions;
- swash and drift aligned lengths usually about shore normal reefs and headlands;

The thesis structure is set out as follows:

Chapter 1 sets out the aims and objectives of the thesis and defines a general mixed sand and gravel (MSG) barrier.

Chapter 2 reviews the physical background of the Hawke Bay MSG barrier coastal environment (relative to the present Mean Sea Level) in terms of the geology, sea level, bathymetry, and climate and storms, atmospheric pressure, wind speed and direction, rainfall, historical storms, tides, swell waves and water currents. More detailed accounts are located in the appendices (expressly the regional and local barrier geology, and the regional and local Holocene sea level changes).

Chapter 3 presents a morphogenic classification of the field sample sites as examples of the wider barrier morphodynamic evolution.

Chapter 4 reviews the local Hawkes Bay historical archives and reports that demonstrate the evolution of the barrier and the human responses to 'erosional events'.

Chapter 5 outlines the morphology and the morphodynamic processes typical of the Te Awanga Hall beachface as representative of the Hawke Bay coarse sediment beachfaces. Photographs illustrate the morphodynamic interactions with the prevailing hydrodynamics of the tides and the infragravity waves, namely the responses of the beachface to erosion and accretional events.

Chapter 6 defines firstly the empirical morphodynamic parameters, secondly, reviews the literature on the use of the empirical morphodynamic parameters, and thirdly, presents a quantitative geometric equation for the beachface cross-shore transverse profile. The morphodynamic equations are the surf scaling parameter (ε) and the Iribarren Number (also called the surf similarity number ξ). The quantitative beachface parameters are the sediment volume changes and the 'profile index' as a geometric beachface shape, namely convex up, linear and concave up. From these parameters a 'type' seasonal, summer – winter, model is developed

Chapter 7 views the cross-shore transverse profile data collected synchronously at five sample sites over 3 y. There are three components to this Chapter. Firstly, the 'seasonal' signatures of the profiles, secondly the nature of the transverse profile as changes of the sediment volume and to the profile index as bivariate and time series plots. Further, the clarification of where on the profile the sediment volume changes take place and how the beachface responds over time. Thirdly, the morphodynamic relationships of the parameters, namely the sediment volume change, the profile index, the breaking wave steepness, the surf scaling parameter and the Iribarren Number as bivariate and time series plots over a 'season'.

Chapter 8 reviews the literature on the sediment textural parameter distributions on MSG beaches. The relationship between the gravel source and supplies is formulated along with conceptual models of distributions in the cross-shore and alongshore directions.

Chapter 9 examines the lower beachface gravel textural sizes (mean grain size, sorting and skewness) over a winter – summer season at four sites in the alongshore wave energy gradient. The McLAREN model (McLAREN and BOWLES, 1985) delineates the nature of the gravel textural changes, for example the repeatability of textural parameter 'states'.

Chapter 10 examines the response of the gravel textural sizes across shore associated with an 'erosional' moderate energy event at three sites alongshore. The morphodynamics shown by the changing cross-shore transverse profiles and breaking wave steepness are also taken into account. Both this event and the high-energy event were of short duration (10 days or less).

Chapter 11 examines the response of the textural gravels in relation to the morphodynamics of a high-energy depositional event at the Te Awanga Hall site. The morphodynamics are shown by changes of the cross-shore transverse profiles and breaking wave steepness.

Chapter 12 examines the morphodynamic relationship of the combined moderate and high wave energy events, to produce a 'definitive' breaking wave steepness boundary between accretional and erosive conditions.

Chapter 13 extends the analysis of Chapters 9, 10, and 11 by applying the gravel forms expressed as the ZINGG (1935) forms (cited BARRETT, 1980) to the same situations viz. seasonal changes and responses to moderate and high energy events. The clast forms are, blades, discs, rods and spheres, and the DOBKINS and FOLK (1970) forms (the two form parameters oblate prolate index (OPI) and maximum projection sphericity (MPS)).

Chapter 14 describes the gravel forms (ZINGG (1935) and DOBKINS and FOLK (1970)) collected from the geological stratigraphic column and the along the only contemporary river (the Tukituki River) supply linking the Ranges to the modern coast. The stratigraphic column gravels came from near the greywacke gravel source (the Ranges) to assess any change of gravel form in geological time (Plio-Pleistocene). Gravels collected from the Cape Kidnappers, (a modern cliff line supply, and a Pleistocene fluvial deposit) could indicate the down river changes of clast form in the Pleistocene and these are comparable to the changes measured along the only contemporary river link.

Chapter 15 is a synopsis of the observations and the conclusions, and presents suggestions for future research.

1.5 Distribution of MSG Beaches in New Zealand and the World.

New Zealand's most extensive MSG beaches are in the South Island (JENNINGS and SHULMEISTER, 2002). In the North Island the most extensive MSG beaches are located in the vicinity of Wellington (CARTER and MITCHELL, 1985; MATTHEWS, 1980, 1983) and Hawke Bay (MARSHALL, 1928,1929).

On a world scale, most MSG coasts occur in higher latitudes on either coasts of the North Atlantic, for example north-east USA and Canada (FITZGERALD and ROSEN, 1987) and western Britain (ORFORD, et al., 1995), whilst others are reported at the South American east coast (ISLA, 1993).

It is considered that MSG beaches are a product of sediment supply and sea level (ORFORD, et al., 1995). These MSG beaches invariably take on a characteristic profile, and it is suggested that the profile is invariably steep and that this in turn is a function of the wave reflection (defined by the surf scaling parameter) (CARTER and ORFORD, 1984).

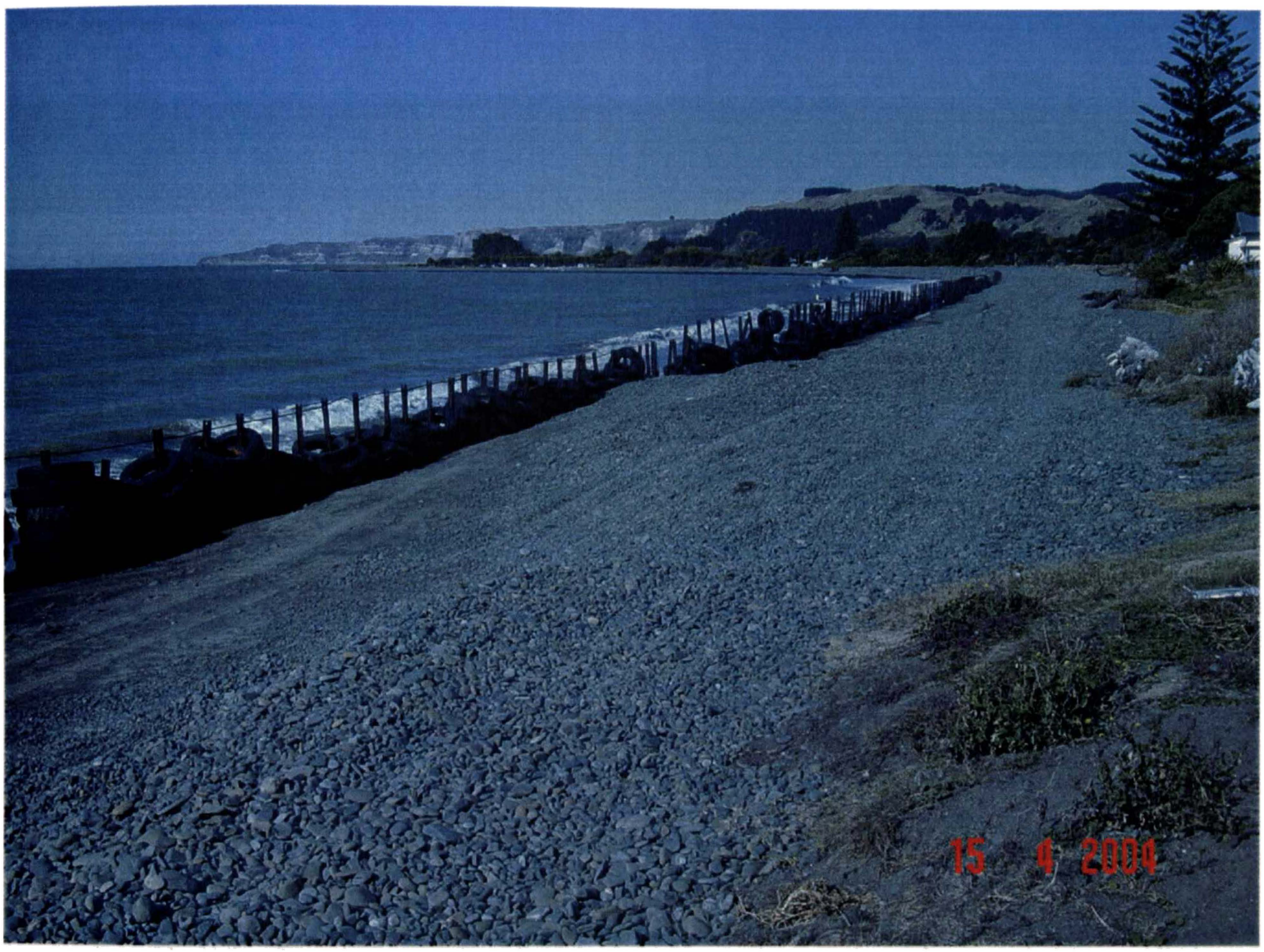
Most MSG beach coastlines occur towards high latitude regions characterised by Quaternary glacial depositional terrains. These are the paraglacial beaches (CARTER, et al., 1987) derived from glacial detritus that contain large proportions of coarse sized material available for supply.

Most MSG paraglacial coasts are characterised by a single, or multiple ridge geomorphology orientated alongshore that often forms a barrier spit. Barriers are considered to result from alongshore progradation of the coarse material released from proximal sources (FORBES et al., 1995) and are recognised "for their propensity to move onshore " FORBES, et al. (1991) and as such are transgressive. Note, the supply of a gravel can be different from the source of the gravel since a source may not directly supply gravels to the beach.

MSG beaches may also form in regions known to be tectonically active, for example the south coast of Crete (POSTMA and NEMEC, 1990).

1.6 Some Wider Topics.

The main investigation centers on the changes of the gravel textures and cross-shore transverse profiles in response to the prevailing breaking wave. However, these general investigations requires placement into context.



(Photograph Terry Healy)

Figure 1.5 View towards Cape Kidnappers from Te Awanga (K2). The beachface is erosional with rail-iron and tyre 'seawall' (16 April 2004) and recent Hastings District Council soil spoil 'protection' right foreground.

Generally, the Hawke Bay barrier has examples of evolutionary stages alongshore according to the classification of FORBES et al. (1995). Evolutionary stages range alongshore from 'initiation' (for example, the swash aligned beach at Clifton near Cape Kidnappers) to 'establishment' (for example, the progradational swash aligned Marine Parade) and 'breakdown' (for example, the swash aligned spit at Haumoana, clearly a breakdown length with barrier crest overwash sediments prior to the construction of a groyne.

Examples of cross-shore transverse profile surveys over several years are rare especially for the gravely beaches. Examples exist for particular sandy beach localities, for example Duck, North Carolina. However, data for gravely beaches appears singularly uncommon with exceptions (CALDWELL AND WILLIAMS, 1985; ORFORD, 1986) and are not at a transgressive roll over beach at a barrier on a plate tectonic margin. We do not know how gravely profiles change in time or where across the profile the greatest and least changes occur. For example, in HB the coastal 'erosion' is an accepted fact but it is not known how the sediment volume and the profile shape (the profile shape index (FUCELLA and DOLAN, 1996) changes over time. Further the morphodynamic links between the beachface slope and the breaking wave remain unclear for gravely beaches, for example WRIGHT et al. (1979) suggest surging waves and HUNTLEY and BOWEN (1975) suggest plunging waves, and ORFORD (1977) suggests spilling waves for upper beachface storm sedimentation.

(Photograph Terry Healy)

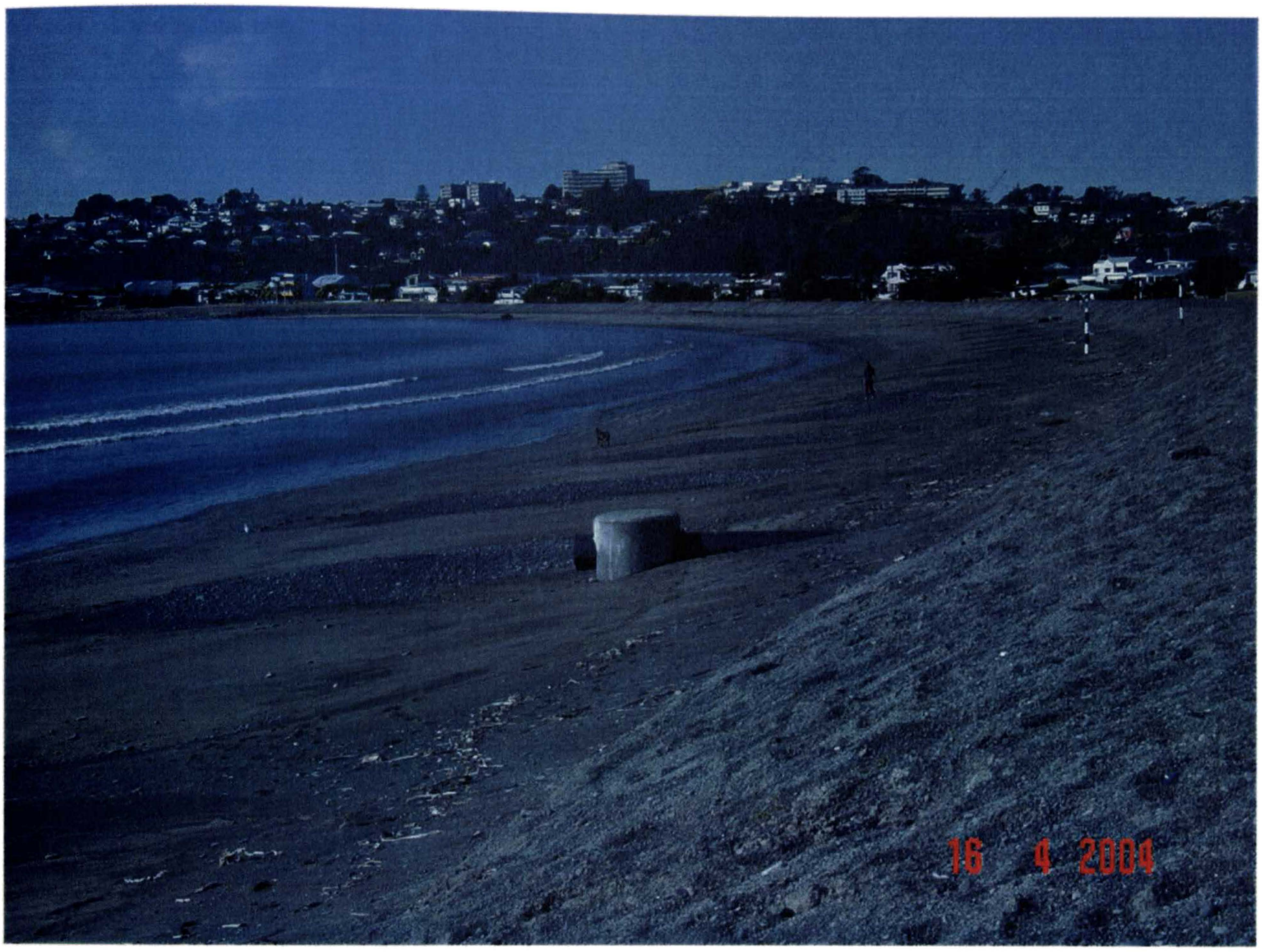
Figure 1.6 View south, Marine Parade (16 April 2004) Napier. Note upper beachface finer gravels compared to those at Te Awanga K2 (Figure 1.5). People are on the storm ridge, just to left and down the beachface slope is a raised High Water ridge.

CARR (1969) and ORFORD (1975) suggest gravel textures change over time but most studies examine beach changes over only a short time frame (SMITH, 1968; SHERMAN et al., 1993; NOLAN et al., 1999). For example (DOBKINS and FOLK (1970) investigated the gravel form devolvement within differing energetic environments and concluded that the gravel forms are indicative to particular environments (high and low energy beaches and riverine). We do not know whether these environmental indicative forms changed over time period or the climatic conditions before sampling.

From observations at the Hawke Bay beach, the most dramatic and energetic environment is at the sub-aerial lower beachface. Gravels sampled from this highly energetic environment should show the greatest changes of size and form in the alongshore direction. It is assumed that these lower beachface clasts represent the most swash active population and any changes of the texture should be the most rapid and noticeable. This assumes few of the clasts pass into storage (buried within the lower beachface) and therefore become protected from the abrasive swash processes. Gravel populations on the beachface can change during high seas events. These changes should reflect in the gravel textural parameters as suggested by SONU (1972) for the sandy beach at Duck, North Carolina. Such parameter changes might repeat in time, for example, the population associated with high seas events might become coarser, well sorted and negatively skewed each time. Gravel forms can have systematic changes associated with storm deposition (SHERMAN et al., 1993). Disc forms transport towards the beach crest in high seas (KING, 1959; KIRK, 1980). If the gravel population available for transport is limited then in a high energy event the clast form sorting will be defined by the forms available. Hence, discs may be transported towards the upper beachface initially but later other forms could transport in the same direction in the same event. Accounts of high-energy depositional overwash at coarse grain beaches (CARTER and ORFORD, 1981) appear to be rare and the changes of sizes and forms associated with similar events very rare. It is possible that overwash deposition and subsequent High Water ridge morphology is a product of successive overwash and overtop deposits each contributing different populations. High seas events can also be erosional and it is possible that the gravel population changes and becomes a lag deposit with characteristic size and form changes. For example, SHULMEISTER and KIRK (1997) suggest high seas run-up winnows fines leaving a coarse residual lag.

The relationship between the gravel grain size and the beachface slope suggest the coarser the grain size the steeper the beachface slope (KING, 1956; KIRK 1980) and likewise the better the sorting the steeper the beachface (KIRK, 1980).

Most studies assume the supply of gravels from an identified source have not changed in geological time. Clast forms may have some bearing on the stability of a gravely barrier system and a change of clast forms may alter the barrier stability. The Hawke Bay barrier greywacke gravels have a distinctive source and occur in stratigraphic conglomerates both near and distal relative to the source (Ruahine Ranges). Since the Ranges are tectonically active having features of uplift and transform faulting, there is considerable clastic sediment deposition both adjacent to the Ranges and along ancient and modern river courses. In Hawkes Bay, an opportunity exists to measure the clast form changes in time and space. For example, the changes of the gravel forms in an ancient river can be compared to those in the modern Tukituki River. The ancient river gravels are from the Pleistocene conglomerates adjacent to the Ranges and at some 60 km distant at the Cape Kidnappers. It is also possible to measure the clast forms over time adjacent to the Ranges and hence any change in geological time (Plio-Pleistocene) of clast forms supplied at the source.



(Photograph Terry Healy)

Figure 1.7 View south towards Napier and Scinde Island (17 April 2004) from Westshore. Re-nourishment berm to right with material from Marine Parade. An erosional beach, typified with exposed storm water outlet cupola.

An undertaking of this research therefore was to extend the time frame of sampling to include as many climatic situations as possible and by extending the sampling time period to encompass situations that include the extreme climatic impacts. By this method, some measure might be obtained of the progress of the gravel textures and the beachface topology over storm events especially an erosional and a depositional event.

The HB has a fairly well defined seasonal wave climate with summer steep seas and winter long period waves (GIBB, 1973). This seasonality of the wave climate could reflect in the textural gravels and the topology. Over the research period, only limited climatic conditions came about, neither cyclonic nor large storm events occurred, however wave overwash of the barrier crest did occur.

CHAPTER 2 PHYSICAL BACKGROUND TO THE SOUTHERN HAWKE BAY.

2.1 Introduction.

This chapter reviews the physical characteristics important to the understanding of the Hawke Bay (HB) mixed sand and gravel (MSG) barrier system with reference to the geological evolution, sea level changes, bathymetry, climate and hydrodynamic factors of tides, waves, and currents.

2.2 The Physical Setting of the Hawke Bay Coastal Environment.

Hawke Bay embraces a large embayment of some 2,000 km^2 which is deeply indented between two peninsular headlands, namely Mahia to the north and Cape Kidnappers to the south (Figure 2.1). This embayed coast has a range of geology characterised by landforms ranging from cliffs, to sandy beaches to muddy inlets. The coastal field site (Figure 2.1) is a 20 km length of the southern HB coastal environment between the smaller headland of Scinde Island and the conspicuous Cape Kidnappers.

2.3 Primary Factors of the Hawke Bay Barrier Evolution (Geology, Sea Level, Bathymetry and Atmospheric Climate).

The evolution of the HB and the modern barrier is highly influenced by its location astride an evolving plate tectonic boundary. Details of the geological and sea level history are outlined in Appendices 1, 2, and 2.1. Co-seismic alterations are known to have affected the area as recently as 1931 with a +1.8 m vertical shift of Ahuriri lagoon and a -0.76 m subsidence at the Tukituki River inlet (HULL, 1990). In northern HB, there is evidence of a tsunami some 6,300 y BP (CHAGUÉ-GOFF, et al., 2002). The tectonic changes of the coastal environment have taken place in conjunction with the eustatic sea-level oscillations since the early Pleistocene (LEWIS, 1973; OTA, et al., 1988; BROWN and GIBBS, 1996).

The HB MSG barrier morphology has both relict and modern landforms exemplified by relict multiple ridges and a single modern ridge in the form of a barrier crest (Chapter 5). The single barrier crest is either a stand-alone feature, or is welded onto the relict multiple ridges. The barrier sediments are characterised by mixed sand and gravel textural sizes with a gravel sized component from readily identifiable supply sites including the Cape Kidnappers Late Pleistocene conglomerates containing hard greywacke clasts in a sandy matrix, and the Tukituki River (at Haumoana) or the Maraetotora (at Te Awanga) River inlets. Note, however, that over the period of sampling for this research (1997 to 2003) there were negligible fluvial gravel discharges. The barrier planform is arcuate between the two hard rock headlands of Cape Kidnappers and Scinde Island. Between these headlands, the barrier crosses a subsiding trough infilled by layers of muds and gravels (see Appendix 1). It is possible these layers dip landwards and time horizons, marked by a characteristic lithologic change (boundary between muds and gravels), indicate non-uniform deposition so that tectonic warping is likely an ongoing process (CARTER and LEWIS, 1976). Indeed the 1931 Napier earthquake may have induced sediment textural changes of the clasts supplied to the coast. For example, the Tukituki River inlet subsided -0.76 m and the change of base level may have changed the fluvial bed gradient and induced a subsequent coarser bed load supply to the coast.

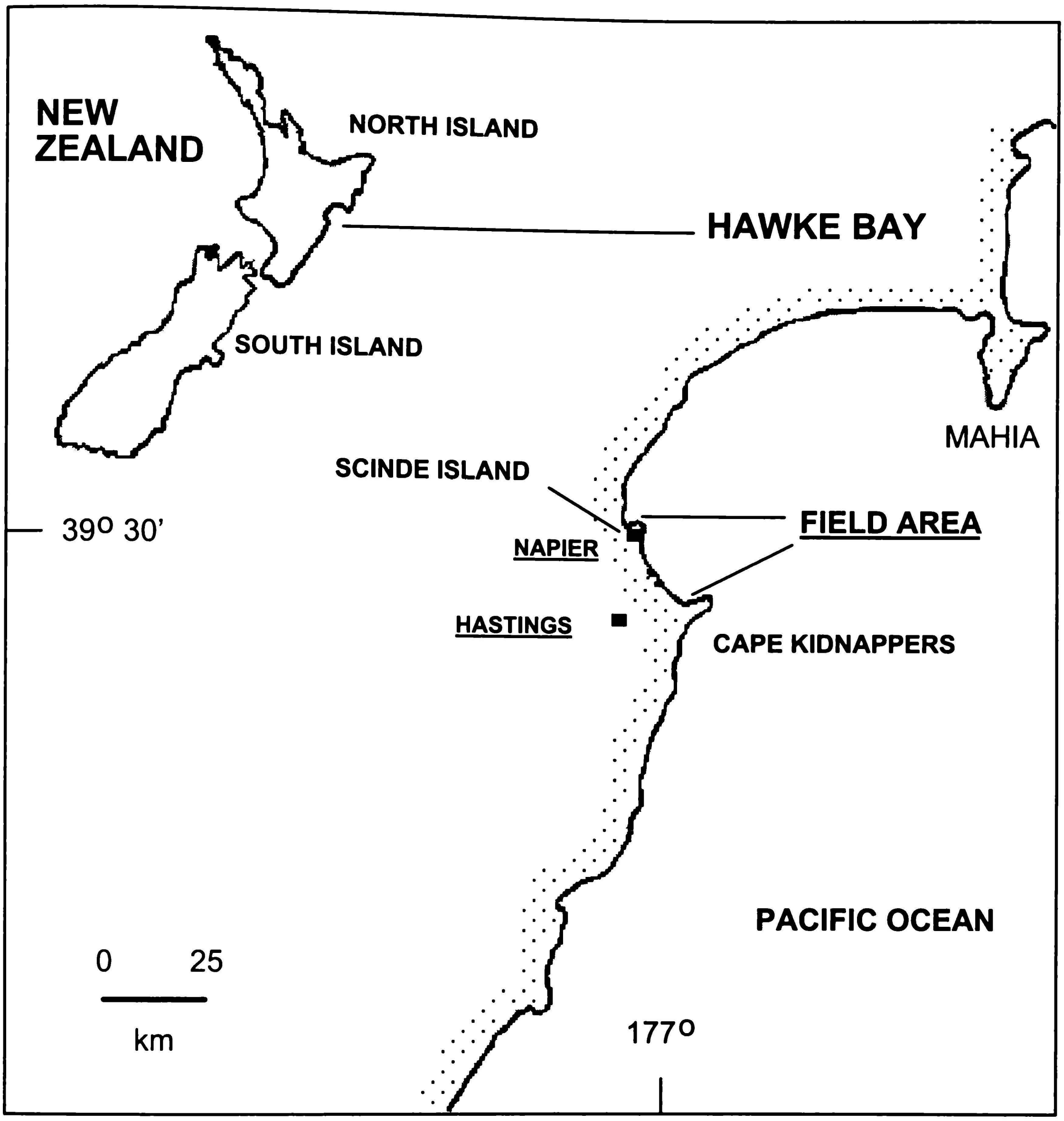


Figure 2.1. Location of Hawke Bay, North Island, New Zealand and the location of the field area in southern Hawke Bay, from Scinde Island to Cape Kidnappers. Also located are the two main population centers of Napier on and about Scinde Island, and Hastings an inland city located on the Heretaunga Plain (10 m above Mean Sea Level).

The Hawke Bay Holocene Sea Level.

The evolution of MSG barrier systems has identifiable temporal scales that include factors such as the Holocene sea level rise and the changing cross-shore morphodynamics (FORBES, et al., 1997). For the HB barrier system, there are two main components to consider. Firstly, the glacioeustatic (eustatic) change is recognised at both the regional scale (CARTER, CARTER and JOHNSON, 1986) and at the local scale (OTA, et al., 1988); and secondly, co-seismic changes have taken place coincident with the Napier earthquake (HULL, 1990).

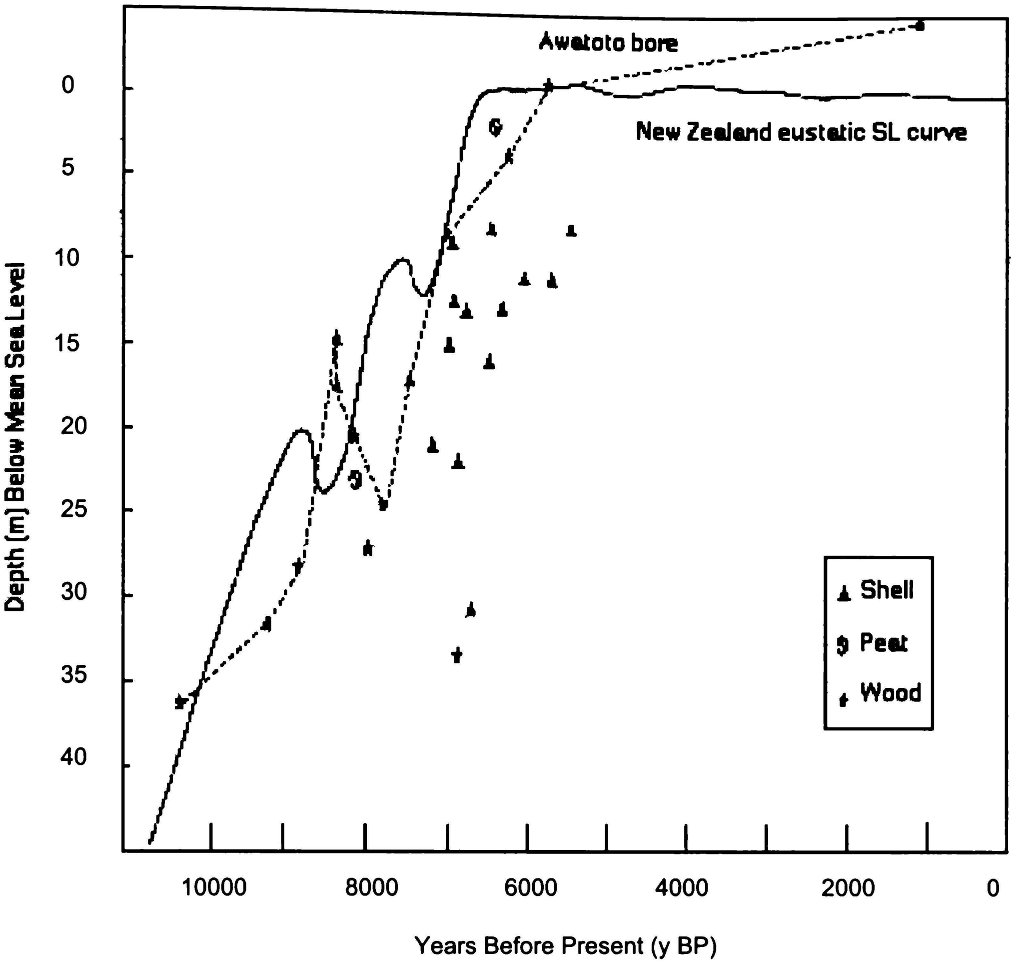


Figure 2.2 Hawke Bay Holocene relative (to modern Mean Sea Level) sea level curve. (BROWN and GIBBS, 1996).

The Holocene sea level (SL) curve of BROWN and GIBBS (1996) (Figure 2.2) indicates the HB SL reached the current 'still stand' some 6,000 y BP and since this time oscillatory peaks of maximum sea level have occurred perhaps as recently as 1,200 y BP, when SL may have stood briefly at +5 m relative to MSL.

Bathymetry.

The inshore bathymetry of the HB is an important factor when considering the evolution of the transgressive barrier system since the bathymetry can change depending upon the sediment flux and the prevailing hydrodynamics and geological processes. A notable characteristic of the HB shallow bathymetry is a break of slope evident at the 10 m isobath (Figure 2.3).

Observations on the bathymetry include:

1). The 10 m isobath is > 2 km offshore north of both the Cape Kidnappers and the Scinde Island headlands and outlines the wide inshore submarine platforms.

2). The 10 m isobath is closer to the shoreline along Marine Parade to the south of the Scinde Island headland which allows a greater wave energy to reach the beachface.

3). There are inshore reefs associated with both headlands. Reefs tend to cross the shore at right angles (forming natural submarine groynes).

4). Irregular isobaths and the reefs suggest an uneven topographic seabed, for example at Pania Reef north-west of Napier port the reef pinnacle is at -1.7 m CD whilst the surrounding sea bed ranges -10.5 m to -14.6 m.

5). Inshore Clifton is uncharted (pers. comm., Hydrographic Office, Royal New Zealand Navy. See chart NZ 56). Indeed the survey ship HMNZS Tarapunga holed after striking uncharted rocks (NAPIER TELEGRAPH, 5 November 1980). Nearshore waters extend from shore to the 10 m isobath and the inshore extends from the shore to the 5 m isobath.

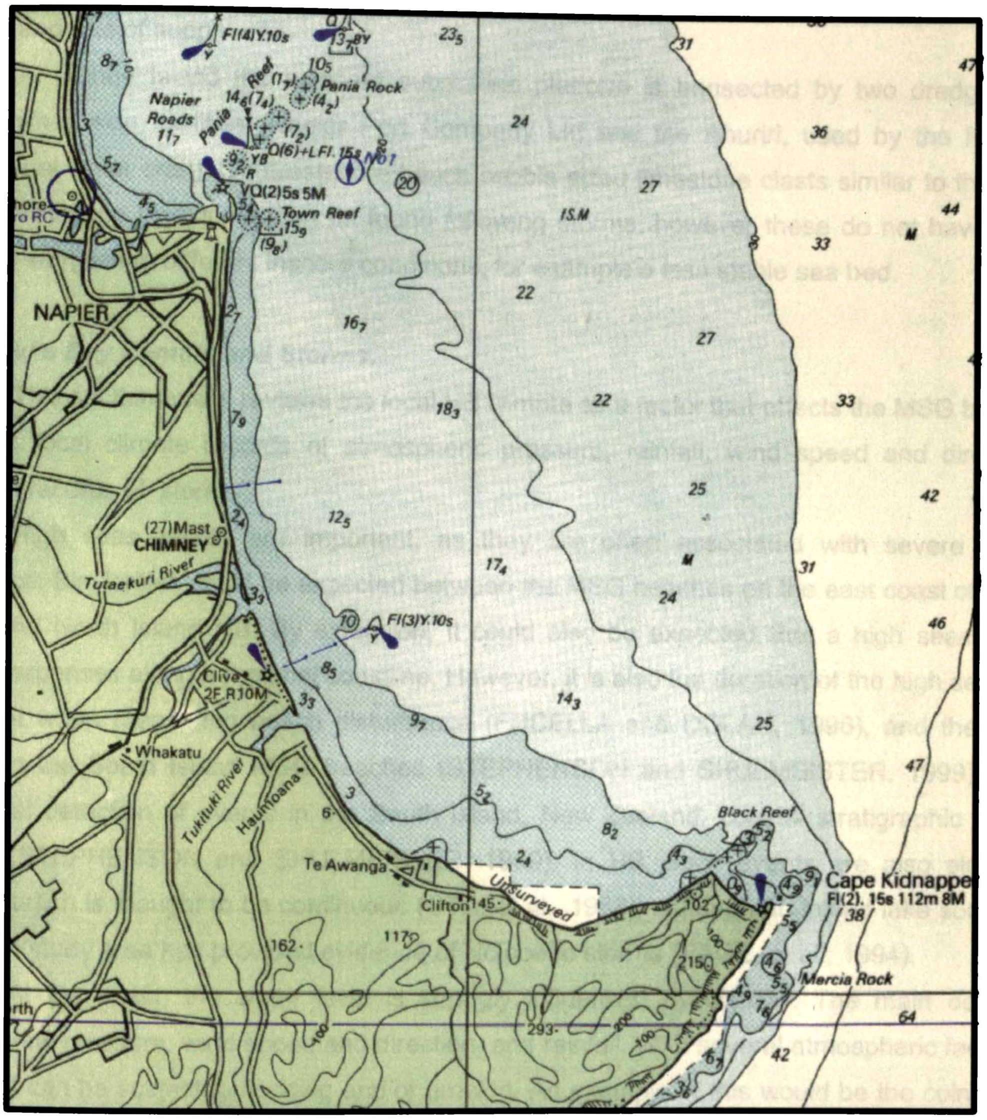


Figure 2.3. The southern Hawke Bay bathymetry. Part of sheet NZ 56 (RNZN). The heights and depths are in metres. Scale 1 cm approximately 2 km.

From observation (Richard Williams pers. comm., 1998) the submarine platform off Cape Kidnappers has deep (up to 6 m), sheer sided gullies that on occasion can fill with sands and possibly act as sediment traps for material moving both alongshore and cross-shore. Cross-shore material can be derived from the Cape Kidnappers during periods of intense rainfall. There is also be an onshore transport component as bottom drifters released off East Clive (Figure 1.1) were found in groups along the Cape beach where the Cape gullies met SL (WHITE, 1994).

The submarine platforms have lithological compositions similar to those outcropping at the adjacent cliff-lines. For example, the submarine platform off Cape Kidnappers can supply "relict gravels" to the HB MSG barrier (PANTIN, 1966). These relict gravels occur on the beach between Clifton and Te Awanga especially following high seas when cobble sized clasts can wash ashore with attached kelp seaweed. These relict clasts also have a similar greywacke composition as those from the Cape Castlecliffian conglomerates. Between Te Awanga and Clifton the submarine platform Castlecliffian rocks can be observed outcropping along the lower beachface and act as a hard bedrock basement over which the contemporary sediments transport as a veneer, and as such can give some estimate of sediment mobility and rate of supply.

At Scinde Island the adjacent submarine platform is transected by two dredged channels to access wharf-side facilities (Napier Port Company Ltd and the Ahuriri, used by the fishing fleet and recreational water craft). On Westshore beach cobble sized limestone clasts similar to the Scinde Island Early Pleistocene limestones can be found following storms, however these do not have kelp seaweed growths, suggesting different inshore conditions, for example a less stable sea bed.

The Hawke Bay Climate and Storms.

This section briefly reviews the local HB climate as a factor that affects the MSG barrier evolution, from the local climate records of atmospheric pressure, rainfall, wind speed and direction, and the historical records of 'storms'.

High seas events are important, as they are often associated with severe erosion of the beachface. Similarities could be expected between the MSG beaches on the east coast of both the South Island and North Island HB. By extension, it could also be expected that a high seas event produce similar responses along a regional coastline. However, it is also the duration of the high seas event that is important when measuring beach disturbance (FUCELLA and DOLAN, 1996), and the succession of events at the South Island MSG beaches (STEPHENSON and SHULMEISTER, 1999). However, the geological detection of events in the South Island, New Zealand, coastal stratigraphic record remains elusive (STEPHENSON and SHULMEISTER, 1999). In HB, such events are also elusive since the sedimentation is thought to be continuous (OTA, et al., 1988), although an inland lake some 12 km north of the HB study area has provided evidence of Holocene storms (PAGE, et al., 1994).

At the coast, the water level is strongly influenced by climate. The main determinants are atmospheric pressure, wind speed and direction, and rainfall. With several atmospheric factors combining the coast can be subject to flooding and/or erosion. An example of this would be the coincidence of high spring tide, onshore winds and low atmospheric pressure. However, such high seas events could lead to overwash deposition similar to that reported by ORFORD and CARTER (1982).

Atmospheric Pressure.

Atmospheric pressure records from a barometer installed at Te Awanga by the author comprise one observation per day. Over the data-gathering period (August 1997 to May 2003) the local (Te Awanga) barometric pressure ranged from a recorded low of 985 mb to a high of 1035 mb. Distal atmospheric pressure gradients generate wave fields which can run to shore in HB as swell waves with breaking wave period (T_b) usually ranging between 6 s and 14 s.

Figure 2.4 is an example of the relationship between the local atmospheric pressure and the observed low water breaking swell wave (see Section Z.4.5 for the definition of B_s, ORFORD, 1977). Figure 2.4 shows an inverse relationship ($R^2 = 88.5\%$, F test is significant at 5 degrees of freedom) between the atmospheric pressure and wave steepness for January 2000. As the pressure decreases the wave steepness increases. Although not expanded upon here, on occasion the low pressure leads the wave steepness increase and on others it lags depending on the proximity and speed of the approaching low pressure systems.

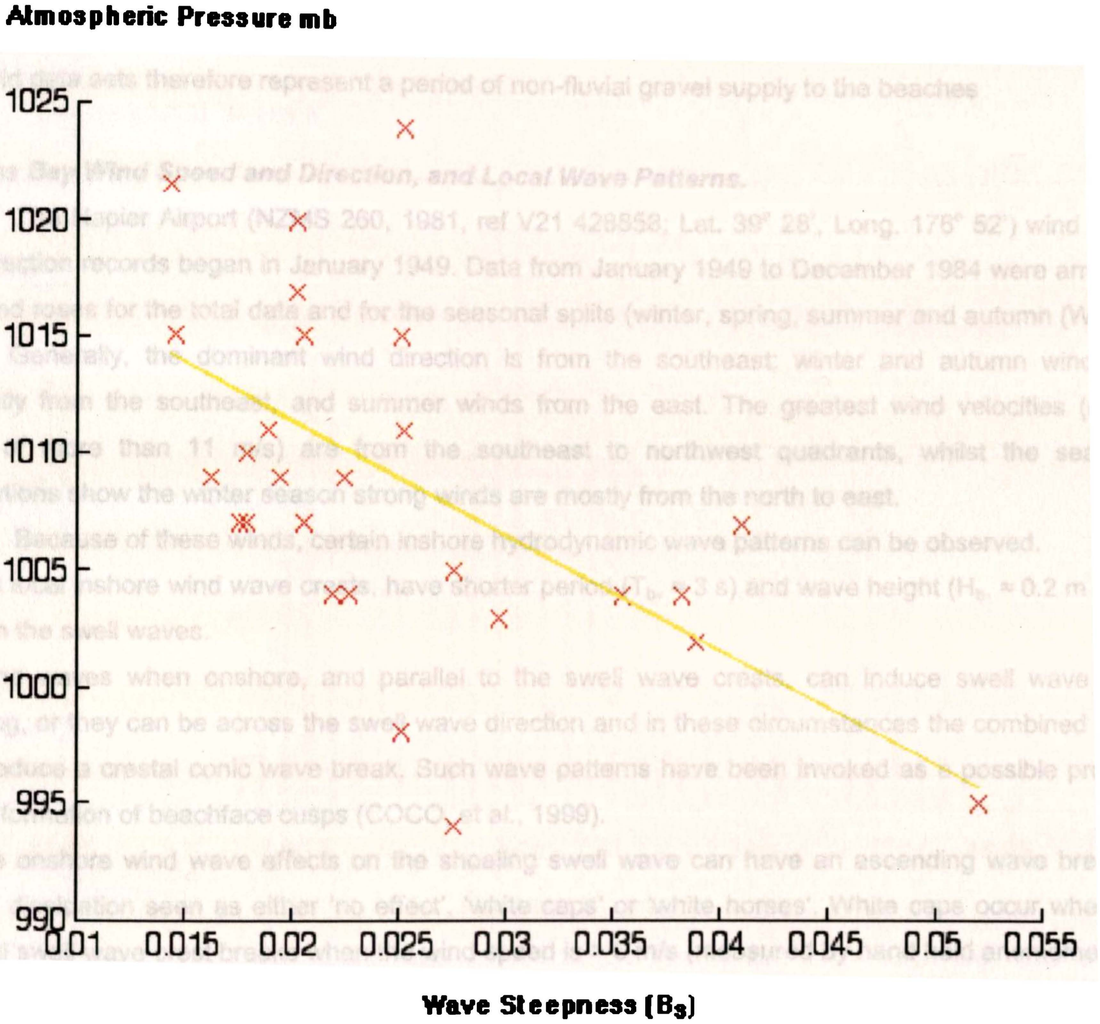


Figure 2.4. Scatter plot of the local atmospheric pressure and wave steepness, January 2000. This data is for Te Awanga Hall. Wave parameters obtained by visual estimate of wave height (m) and period (s) and derived breaking wave steepness (B_s) (ORFORD, 1977). Atmospheric pressure was from the author's barometer.

In New Zealand low atmospheric pressure, cyclonic events are associated with erosion along the east coast of the South Island (STEPHENSON and SHULMEISTER, 1999). Ex - tropical cyclones track from the north - east and down the east coast of the North Island and whilst intense single cyclones can have considerable impact, a series of less intense cyclonic events can also have severe impact as the time for the beachface to recover by sediment deposition is too short (STEPHENSON and SHULMEISTER, 1999). High seas events under cyclonic conditions have an effect on the HB MSG barrier active beachface. For example, sheets of coarse sediments can be transported landwards as overwash by the prevailing climatic storms similar to that described by ORFORD and CARTER (1982,

1985) for southern Ireland. At the HB barrier beachface, sediments can transport landwards as overwash sheets across the High Water ridge (HW ridge) (Chapter 10, 11 and 13) towards and even on occasion over the beach crest.

Hawkes Bay Rainfall.

Rainfall can be important to the HB coastal morphodynamics. Rainfall can cause coastal flooding, and river discharge can inject gravels at the coast via one of the gravel transporting rivers (Maraetotora, and Tukituki). Over the total period of gathering data for both the gravels and the transverse profiles, there were no rainstorm events with subsequent inshore gravel deposition derived from river discharge. The field data sets therefore represent a period of non-fluvial gravel supply to the beaches

Hawkes Bay Wind Speed and Direction, and Local Wave Patterns.

The Napier Airport (NZMS 260, 1981, ref V21 428858; Lat. 39° 28', Long. 176° 52') wind speed and direction records began in January 1949. Data from January 1949 to December 1984 were arranged into wind roses for the total data and for the seasonal splits (winter, spring, summer and autumn (WHITE, 1994). Generally, the dominant wind direction is from the southeast; winter and autumn winds are generally from the southeast, and summer winds from the east. The greatest wind velocities (strong winds of more than 11 m/s) are from the southeast to northwest quadrants, whilst the seasonal distributions show the winter season strong winds are mostly from the north to east.

Because of these winds, certain inshore hydrodynamic wave patterns can be observed.

1). The local inshore wind wave crests, have shorter period (T_b, ≈ 3 s) and wave height (H_b, ≈ 0.2 m to 0.3 m) than the swell waves.

2). Wind waves when onshore, and parallel to the swell wave crests, can induce swell wave crest breaking, or they can be across the swell wave direction and in these circumstances the combined effect can produce a crestal conic wave break. Such wave patterns have been invoked as a possible process for the formation of beachface cusps (COCO, et al., 1999).

3}. The onshore wind wave effects on the shoaling swell wave can have an ascending wave breaking energy dissipation seen as either 'no effect', 'white caps' or 'white horses'. White caps occur when the isolated swell wave crest breaks when the wind speed is > 5 m/s (measured by hand held anemometer at the beach crest) and white horses are the more widespread and persistent swell wave crest breaks and occur when the wind speed > 10 m/s or Beaufort wind force 3 to 4.

4). Wind waves are often not present when swell waves overtop or overwash the beach crest. There is a distinction between overtop and overwash. Overtopping is the landward transport of seawater to a ridge or crest and sediments that deposit either on the crest of the ridge, or to seaward of the ridge and 'weld' onto the ridge. Overwash is the landward transport of seawater and a sediment population beyond a ridge or crest, and at the HB coast, these can be sands and/or gravels sizes.

Historic Storms in Hawke Bay.

The history of HB storms associated with high seas helps place the fieldwork data sets into an evolutionary context of a continuum that can range between a steady state (a long period of fewer storms), and non-steady state (a long period of frequent storms).

SMITH (1984) produced a list of storm events and accompanying high sea states since 1810. Records are fragmentary and perhaps contradictory. For example, a storm event in February 1936 is described for the South Island east coast as a "severe ex-tropical" (STEPHENSON and SHULMEISTER, 1999) but is apparently unrecorded in the HB records.

Figure 2.5 summarises storm events that could have impacted upon HB between 1810 and 1985 sourced from SMITH (1984); STEPHENSON and SHULMEISTER (1999); PAGE, et al. (1994) and records from the NAPIER TELEGRAPH newspaper. The frequency of storms depends upon the length of the time intervals chosen, for example in ten years the average frequency of storm events is 6.4/10 y. In a five-year time interval, that chosen for Figure 2.5, the average frequency is 3/5 y.

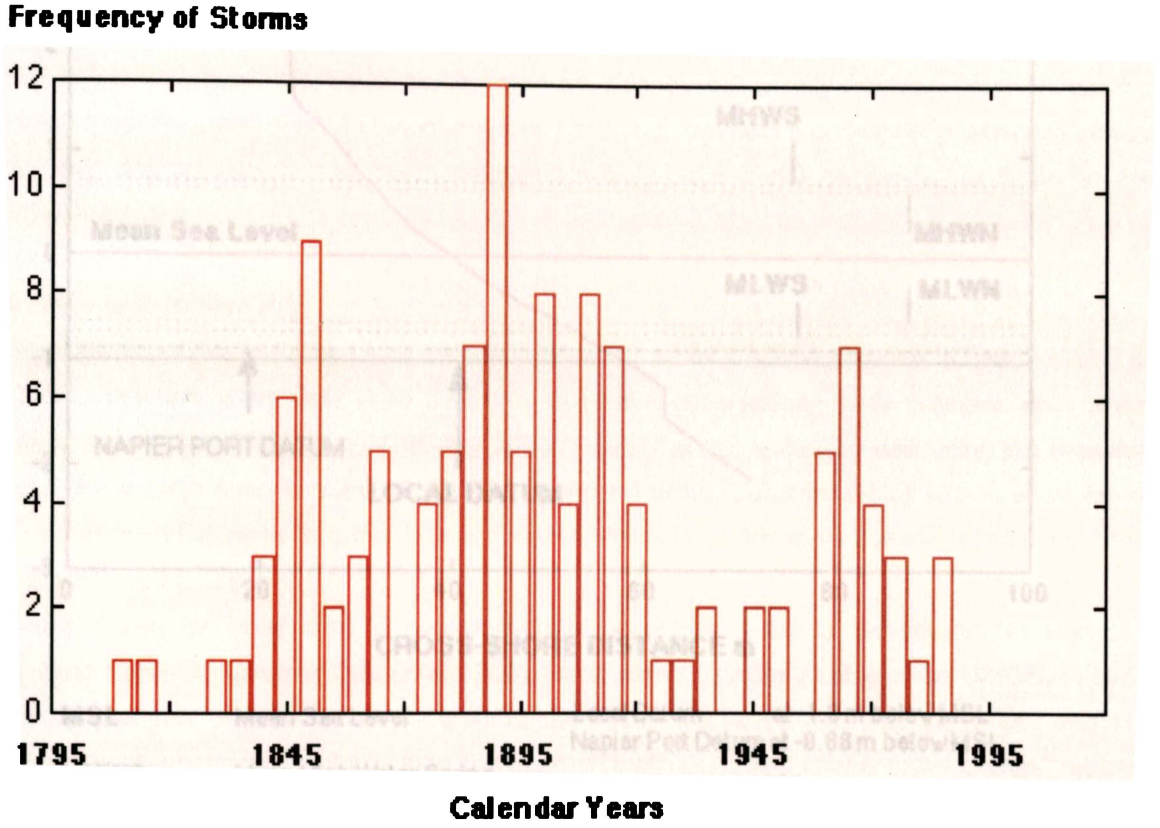


Figure 2.5. Frequency of storm events reported in southern Hawke Bay over the period 1810 to 1985 (after SMITH (1984); STEPHENSON and SHULMEISTER (1999); PAGE et al. (1994) and the NAPIER TELEGRAPH).

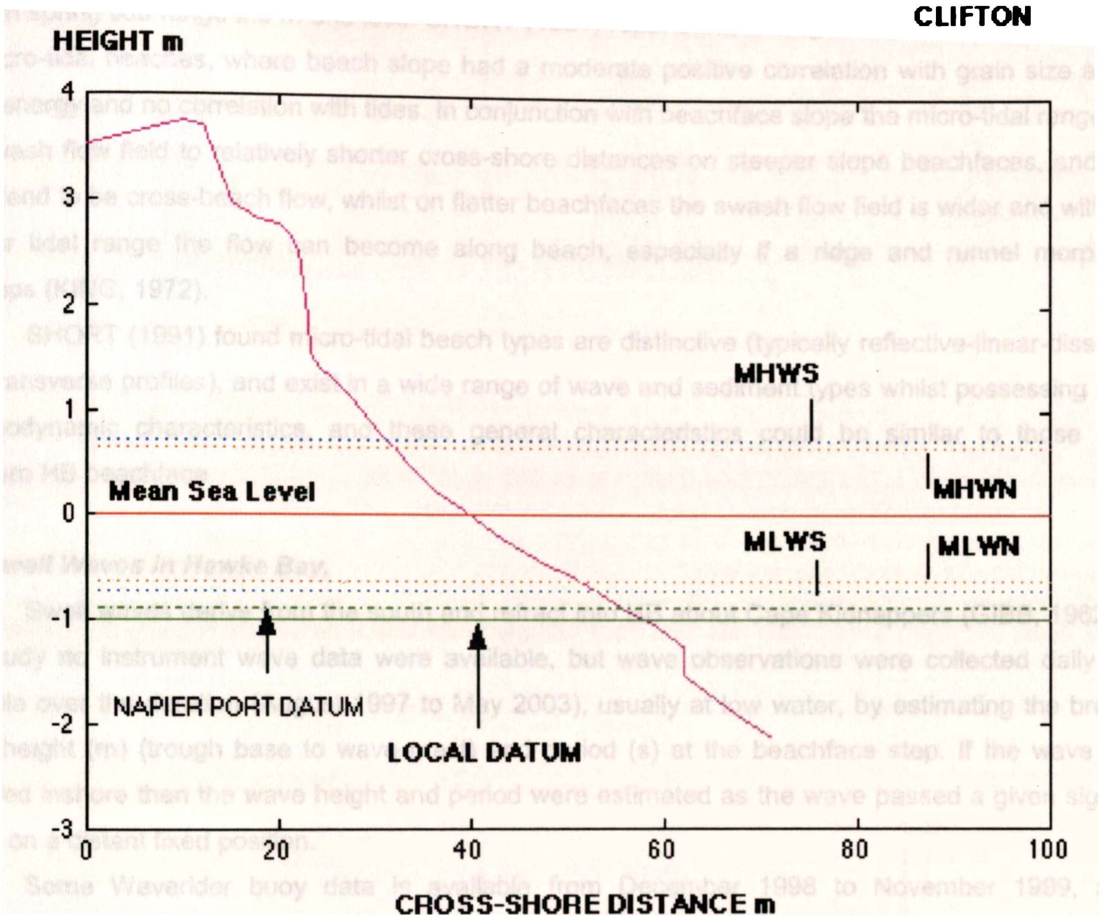
Figure 2.5 also suggests the frequency of storm events has changed since records began, with a greater storm frequency in the late 1800's and subsequent decline of storm events until an outlier of the 1960-1970s, and further decrease of frequency, indeed the last major cyclonic storm in HB was cyclone Bola in 1988.

2.4 Hydrodynamic Factors Affecting the Southern Hawke Bay Barrier.

The HB barrier beachface evolution can be viewed as a series of morphodynamic responses to the prevailing contemporary hydrodynamic factors comprising tides, waves and currents.

The Southern Hawke Bay Tidal and Beachface Morphodynamics.

The tidal cycle in HB is semidiurnal with a spring range of 2.0 m and a neap range of 0.9 m relative to the local Port of Napier datum at Bench Mark (BM) H 40, from which the lowest astronomical



MSL	Mean Sea Level
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MHWN	Mean High Water Neaps
MLWN	Mean Low Water Neaps

Napier port datum tide levels

MSL	0.0 m
MHWS	+0.72 m Spring
MLWS	-0.72 m Spring
MHWN	+0.64 m Neaps
MLWN	-0.64 m Neaps

Local Datum at -1.0 m below MSL
Napier Port Datum at -0.88 m below MSL

Date 6 October 1998
survey time 1247 NZDT

Tide low water 1227 0.0 m
Springs 1.7 m

Measured in field
Low tide at 56 m
(cross-shore distance)
Water depth at last data 1.1 m

Note the difference between the measured low tide and that predicted by Napier port tidal gauge.

Figure 2.6. Tidal and local datum transposed onto a cross-shore transverse profile at Clifton.

tide is measured (NEW ZEALAND NAUTICAL ALMANAC, 1999). An example of the HB tidal levels and datum are shown transposed onto an example transverse profile for Clifton (Figure 2.6). Similarly, the tidal levels and datum for all sites are located in Appendix 8. Within HB generally the flood tide flows are to the north and the ebb tide flows to the south (RIDGWAY, 1962).

HB tidal records are incomplete (for example records are missing, (pers. comm., Brian Gestro), and an instance of a broken tidal station (pers. comm., Hydrographic Office, Royal New Zealand Navy) and several methods have been used to record tidal water levels.

Following the classification of SHORT (1991) for Queensland, Australia, the HB is micro-tidal with a mean spring tide range 2.0 m and less. SHORT (1991) reports the findings of KING (1972) for 27 micro to macro-tidal beaches, where beach slope had a moderate positive correlation with grain size and the wave energy and no correlation with tides. In conjunction with beachface slope the micro-tidal range limits the swash flow field to relatively shorter cross-shore distances on steeper slope beachfaces, and these flows tend to be cross-beach flow, whilst on flatter beachfaces the swash flow field is wider and with even greater tidal range the flow can become along beach, especially if a ridge and runnel morphology develops (KING, 1972).

SHORT (1991) found micro-tidal beach types are distinctive (typically reflective-linear-dissipative type transverse profiles), and exist in a wide range of wave and sediment types whilst possessing similar morphodynamic characteristics, and these general characteristics could be similar to those at the southern HB beachface

The Swell Waves in Hawke Bay.

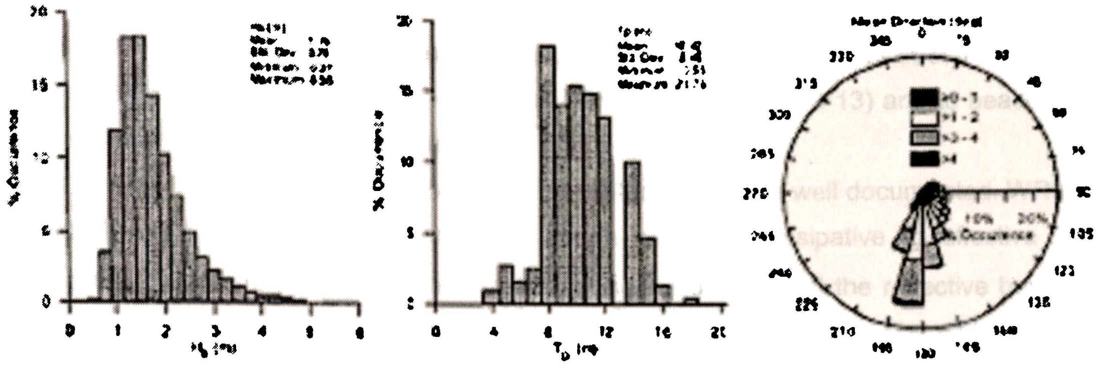
Swell waves derive from the south and refract into HB about Cape Kidnappers (GIBB, 1962). For this study no instrument wave data were available, but wave observations were collected daily when possible over the duration (August 1997 to May 2003), usually at low water, by estimating the breaking wave height (m) (trough base to wave crest) and period (s) at the beachface step. If the wave break occurred inshore then the wave height and period were estimated as the wave passed a given sight line based on a distant fixed position.

Some Waverider buoy data is available from December 1998 to November 1999, and a MetOcean buoy between April and September 2000 (pers. comm., Andrew Laing). The MetOcean buoy was located about half way between Cape Kidnappers and Mahia (177.39° E, 39.50° S) and the Waverider was positioned about half way between the MetOcean buoy and Napier (pers. comm., Andrew Laing). Shallow water, longer duration instrumentation was deployed by the Port of Napier and positioned north of the port at a water depth of -15 m (chart datum), in August 2000 (ANDREWS, et al., 2003).

Instrument recorded wave data statistics are relatively recent and as a consequence a HB wave climate (deep water) option has been introduced (ANDREWS, et al., 2003) based upon WAM hindcasting (GORMAN and STEPHENS, 2003). These models do not yet run the hydrodynamic wave to the inshore (water depth < 10 m (pers. comm., ANDREWS) or shoreline and beachface.

There are similarities between the WAM model and the field observation wave (WHITE 1997 to 2001) parameter frequency distributions in that neither have Gaussian distributions. ANDREWS, et al. (2003) show histograms of WAM derived wave statistics from "Two-dimensional 3 hourly wave spectra from the WAM wave model was obtained from Dr. R. GORMAN at the -200 m CD (coastal datum) contour at the entrance of Hawke Bay", (Figure 2.13). The position of the WAM cell model generated wave spectra, ANDREWS, et al. (2003) is approximately 177.21° E and 39.46° S. The WAM model is based upon synoptic wind data from 1979 to 1998, with the most accurately recorded data since 1994. ANDREWS, et al. (2003) conclude the wave climate is swell wave dominated where this is offshore (continental shelf-slope). The WAM parameters, from 1979 to 1998, suggests in deep water (isobath at -

200 m) off Cape Kidnappers the average wave height, $H_o \approx 1.76$ m, and period, $T_o \approx 10.42$ s, and according to equation 1, the average deep wave steepness $H_o/L_o \approx 0.01038$.



(ANDREWS, et al., 2003)

Figure 2.7 Hawke Bay continental slope WAM model hindcast wave statistics, frequency percent histograms. (centered on 177.21°E; 39.46°N, in 200 m of water). Left histogram is deep-water significant wave height (Hs) (m); right histogram is deep water period (T_p) (s). X-axis H_s units 0 to 6 (m); T_p 4 units, 0 to 4, 4 to 8, 8 to 12, 12 to 16, 16 to 20 s. H_s statistics are mean 1.76 m; standard deviation 0.73; minimum 0.37; maximum 8.56, and T_p statistics are mean 10.42 s; standard deviation 2.46; minimum 3.56; maximum 21.76. On the far right is a wave direction rose plot segmented at 5° intervals, percent occurrence is at 5% intervals from 0 to 25%, (heights H_s (?) (m) are > 0-1; >1-2; >3-4; >4 (with no >2-3 m).

$$\frac{H_o}{L_o} = 2\pi \frac{H_o}{gT^2} \qquad (1)$$

where

H_o is deep water wave height

L_o is deep water wave length

g is the acceleration of gravity

T is the deep water wave period

(CERC, 1984)

The only inshore-instrumented wave data parameters recorded recently (November, 1997) are for Westshore BLACK and VINCENT (2001). At Westshore, divers recorded a shore normal wave and the wave parameters gave a significant wave height (H_s) ≈ 0.42 m, and wave (peak spectral) period (T_p) ≈10.3 s, where these parameters give a wave steepness of ≈ 0.0025 (for derivation see equation 1).

Hawke Bay Swell Wave Parameters, Observation.

This study uses daily field observation data (notes and photographic records, WHITE, 1988 to 2003) to determine the breaking wave steepness at the study site. Wave data omissions occur, usually because the author was away, for example at the University library. The wave steepness relationship is applied to sediments (textural sizes and clast forms) and morphodynamic indicators as expressed by cross-shore transverse profiles. As a first approximation, the breaking wave steepness can be related to the morphodynamics, or beachface slope, by the Iribarren number (BATTJES, 1974) (see Chapter 6 for

Iribarren number definition used in this study). BATTJES (1974) suggests the Iribarren number can be used to classify the beach reflectivity, as reflected wave steepness (ξr) which has been measured and demonstrated in the field by MASON (1997) for a beach in Wales. JENNINGS and SHULMEISTER (2002) have shown the Iribarren number to be useful as a field classification for the many mixed sand and gravel (MSG) beaches in the South Island, New Zealand. These morphodynamic parameters are related to gravel facies and increasing breaking wave steepness (Chapters 10, 11 and 13) and to beach profile parameters, for example sediment volume (Chapter 7).

The relationship between the incident wave and beachface slope are well documented. WRIGHT, et al. (1979) classified and linked the morphodynamic beach into either dissipative or reflective based upon the surf scaling parameter (ε) (defined in Chapter 7) and suggested that the reflective beachface cuspate morphology could be linked to edge waves (where this is the reworking of HW ridge). The surf scaling parameter has also been applied to the morphodynamics of MSG beaches in northern Ireland and the link between beachface reflectivity and the initiation of edge waves (SHERMAN, et al., 1993). Reflective beaches characteristically have low value surf scaling parameters, and as the surf scaling parameter reaches and falls below 2.5 the beachface reflectivity increases “and substantial reflection will occur”. Over a period of time, HUGHES and COWELL (1987) demonstrated at an embayed beach in Australia the links between the surf scaling parameter (ε) and the reflective nature of the beach profile and the alterations of the beach profile to the wave breakers

Indeed, whilst observing and sampling the active HB beachface the wave could arrive at the step in a variety of patterns. Some, as readily identifiable wave trains (time separated groups of high breaking waves) and others as trapped waves (recognised as high water levels off the step that can form a wave sometimes propagating to shore, and can break as a wave at the swash run-up zenith.

The observed (from the beach crest) breaking wave parameters are summarised in Figure 2.8, (H_b); Figure 2.9, (T_b) and Figure 2.10, (B_s) (wave steepness B_s (ORFORD, 1977) is defined in Chapter 6

The Figures 2.8 (H_b) and 2.10 (B_s) are positively skewed with (H_b) skewed towards smaller wave heights (with a large wave height tail) and wave steepness (B_s) skewed towards smaller steepness waves. Wave height (H_b) is polymodal and has several outliers (isolated counts centered on 1.7, 2.0, 2.5, 3, and 3.9 m). The breaking wave period (T_b) Figure 2.9 has almost a Gaussian distribution outline, however the histogram peaks are not smooth and there is a longer wave period tail with an outlier at some 18 s. The wave steepness (B_s) distribution curve (Figure 2.10) is smoother, but modes are present, for example at some 0.057, and there is an outlier at about 0.096.

The parameter ‘anomalies’ of polymodality and outliers are a facet of observational data gathering, for example it is reasonable to estimate a breaking wave height of 2.5 m or 3.0 m but

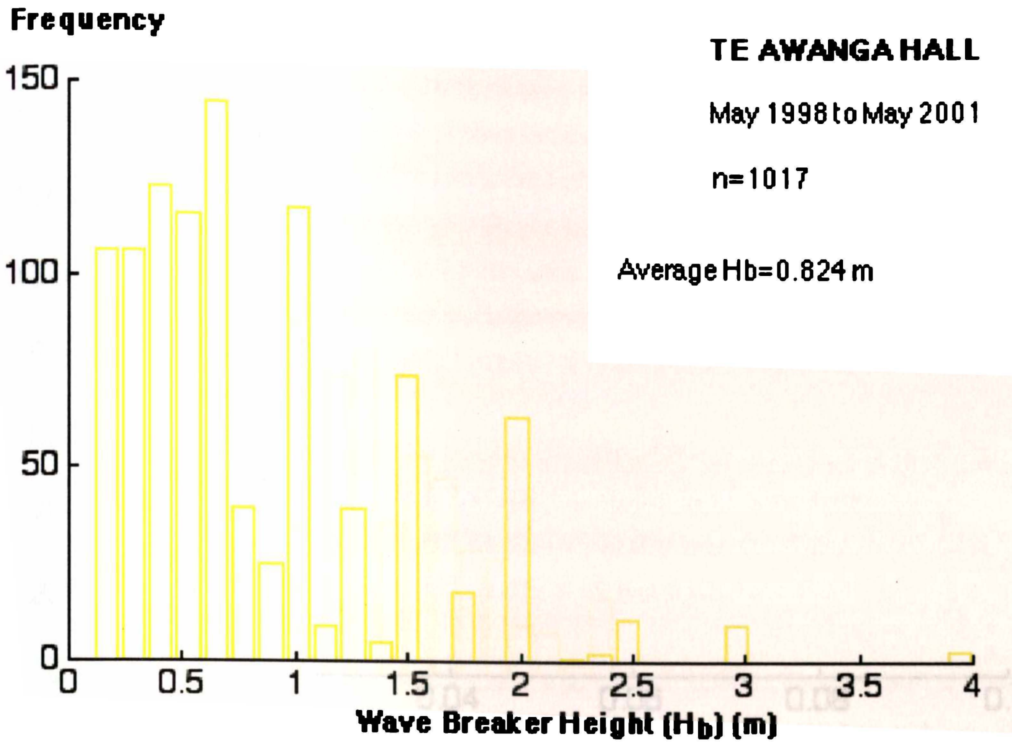


Figure 2.8 Te Awanga Hall observed breaking wave height (H_b) m. Wave height is estimated between wave trough and the following wave crest height at peak breaking at the step, or inshore breaker zone. Inshore waves invariably break some 10 m to 20 m seaward of the step.

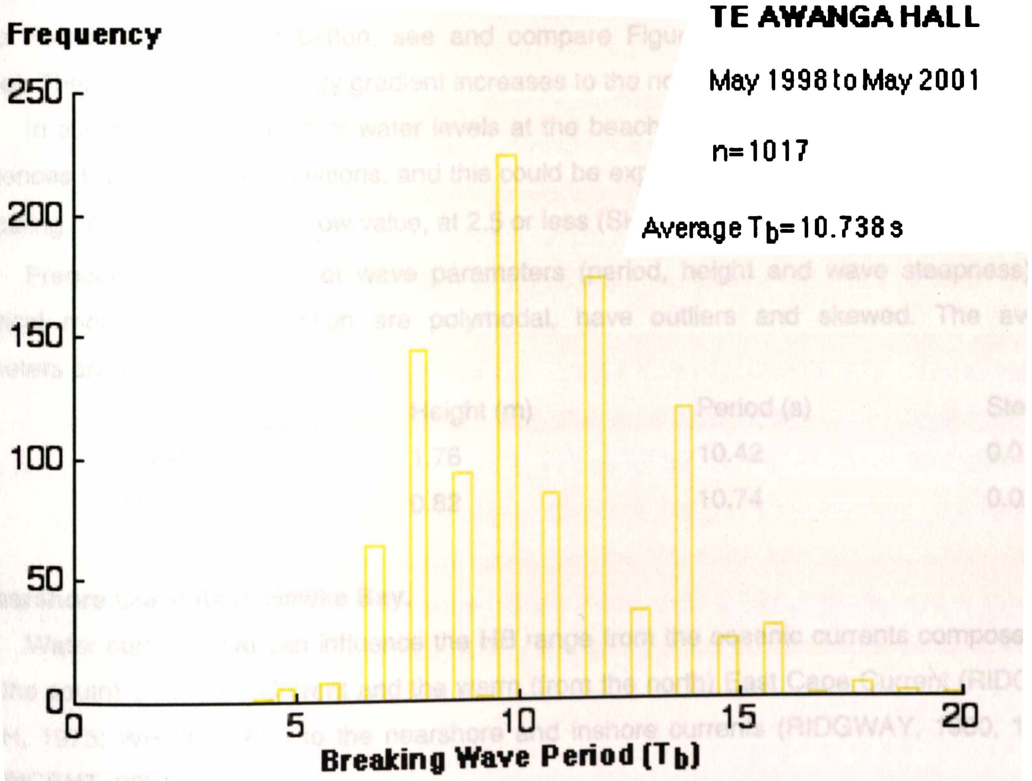


Figure 2.9 Te Awanga Hall breaking wave period (T_b) s. Wave period is estimated as wave breaker passing a given point of reference at the step, or in high energy the inshore.

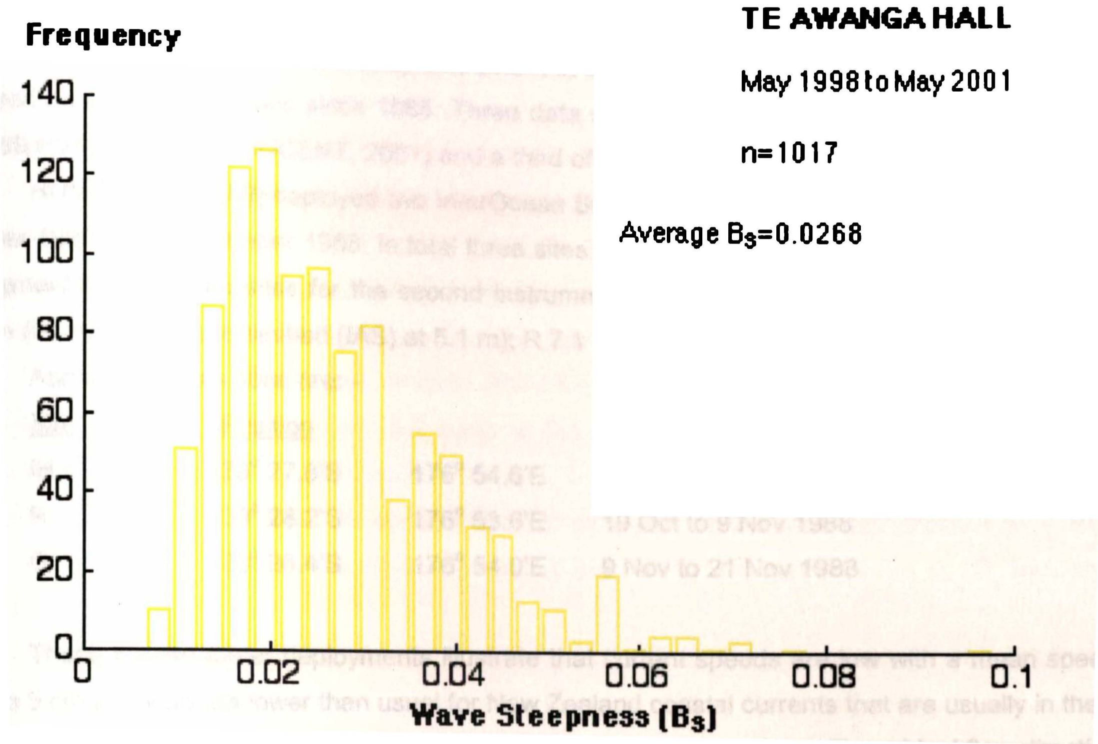


Figure 2.10 Te Awanga Hall breaking wave steepness (B_s).

differences between 2.6 m and 2.7 m are more difficult to determine. Therefore, the breaking wave parameters are an approximation. Observation showed that the breaking wave heights are greater at Marine Parade compared to Clifton, see and compare Figure 10.2 (Clifton) to Figure 10.5 (Marine Parade). Therefore, a wave energy gradient increases to the north.

In summary observation of water levels at the beachface step suggest the HB MSG beachface experiences trapped wave oscillations, and this could be expected off a reflective beach, especially if the surf scaling parameter (ε) has a low value, at 2.5 or less (SHERMAN, et al., 1993).

Frequency distributions of wave parameters (period, height and wave steepness) both WAM numerical model and observation are polymodal, have outliers and skewed. The average wave parameters are:-

	Height (m)	Period (s)	Steepness
WAM	1.76	10.42	0.01038
Observation	0.82	10.74	0.0268

2.5 Nearshore Currents in Hawke Bay.

Water currents that can influence the HB range from the oceanic currents composed of the cold (from the south) Southland Current and the warm (from the north) East Cape Current (RIDGWAY, 1960; HEATH, 1975; WHITE, 1994) to the nearshore and inshore currents (RIDGWAY, 1960, 1962; BLACK and VINCENT, 2001).

Two methods of measuring currents in HB are the fixed point (Eulerian) and the drifter (Lagrangian).

Fixed Point (Eulerian) Water Current Measurements.

Water current measurements by instrument in shallow water (water depth less than 15 m) have occurred on an irregular basis since 1985. Three data sets are available, two off Westshore (HUME, et al.,1989 and BLACK and VINCENT, 2001) and a third off East Clive (pers. comm., David Roper).

HUME, et al. (1989) deployed two InterOcean S4 recording current meters off Westshore from 19 October 1988 to 21 November 1988. In total three sites were occupied. A control site (site IH) and a split deployment between two sites for the second instrument, to sites R and G. The water depths were IH 11.7 m (instrument above seabed (IAS) at 5.1 m); R 7.1 m (IAS at 3.3 m); G 7.0 m (IAS at 3.3 m).

Approximate positions are: -

Site	Position		Duration
IH	39° 27.8'S	176° 54.6'E	19 Oct to 21 Nov 1988
R	39° 28.2'S	176° 53.6'E	19 Oct to 9 Nov 1988
G	39° 28.4'S	176° 54.0'E	9 Nov to 21 Nov 1988

These current meter deployments illustrate that current speeds are low with a mean speed of 3 cm/s to 5 cm/s. These are lower than usual for New Zealand coastal currents that are usually in the range of 10 cm/s to 12 cm/s. Current flows were parallel to bathymetric contours with residual flow directions. At sites IH and R the residual flow is to the southeast, and site G to the east. About 20-30 % of the current is due to tides. Other current flow components are recognised as the long term meteorological forcing and an 'embayment circulation'. Residual tidal flow accounts for the bulk. Winds have little effect on water currents at mid to bottom currents according to HUME, et al. (1989) but this is questionable given the dominance of offshore winds.

BLACK and VINCENT (2001) deployed an instrument array during November 1997, in a water depth of 1.75 m near the Westshore, Napier surf club. The wave breaker was reported as 5 m to 10 m shoreward of the instrument array. Insitu currents were measured using an Acoustic Doppler Velocimeter (Sontek ADV). Currents are reported as generally weak, both the along-shore and cross-shore flows are in the order of 0.1 cm/s, although peak flows of 3 cm/s to 4 cm/s were recorded (BLACK and VINCENT, 2001).

There are unpublished data available for off East Clive (Water Quality Centre, Hamilton, pers. comm., David Roper) from two ANDERRAA impeller-vane assemblies. The Clive instruments were deployed from 20 May to 19 June 1985 at a position of about 39° 34.6'S and 176° 58.2'E in a water depth of some 13 m (instruments 6.5 m above seabed). Over the period of deployment, the weather became rough with an east moving atmospheric low pressure (the Chatham Islands to the east of HB had the greatest wind speeds on record pers. comm., Steve Reid, with 23 knot winds and 4 m swell). At the ANDERRAA deployment site the on/offshore and longshore currents attained speeds of 40 cm/s with a residual flow to the southeast.

Drifter (Lagrangian) Water Current Measurements.

Previous investigations of water current movement patterns in HB have utilised both surface drifter cards (RIDGWAY, 1960, 1962) and drogues (BRADFORD, et al., 1980). Experiments using similar methods (bottom drifters and drogues) were carried out by the author (WHITE, 1994).

RIDGWAY (1960) deployed drifter cards on a grid pattern across the entire HB and demonstrated an oceanic current stream enters HB along a mid line axis moving east-west and on nearing the shore divides into two flows, one to the north, which exits HB round Mahia peninsular, and a southern flow which exits the HB round Cape Kidnappers. Using similar methods, drifter cards and dye patch, along a length of coast between Clifton and Awatoto RIDGWAY (1962) measured the inshore surface currents with drift cards and found speeds of 0.2 knots to 0.4 knots towards the north. RIDGWAY (1962) also suggested an inshore clockwise circulation cell (gyre) along the same length of coast, with inshore drift to the north and nearshore drift to the south. A further gyre, with a clockwise circulation may exist to the north off Napier port (and off Westshore), (McCOMB, 2001) as identified by a 3D hydrodynamic numerical model.

The inshore north flowing current is generated by incident wave refraction (RIDGWAY, 1962). Indeed, in high seas a strong shore parallel current flows off Clifton, Te Awanga, Haumoana, and Marine Parade. The currents have a surface flow 1.0 m/s to the north, in an inshore water depth of some 1.0 m to 2.0 m, and an off beach width 20 m to seaward measured by flotsam. These currents flow when the incident swell wave is a ground swell with steady period T_b 12 s to 14 s, with long flat wave troughs and short asymmetric wave crest, at LW. The current can pulse with 'steady' flow when the wave trough is off the step, to a decreased flow as the wave crest approaches the step, and an accelerated flow as the wave crest passes and the wave height rapidly decreases. In tranquil time, at the step a current to the north from Clifton to Marine Parade flows, so that backwash plumes from weakly cuspate bays drifts north. As cusp topography increases the flow circulation patterns increase velocity and flow directions can be locally to the south.

Drogue measurements of water currents in the central HB and off Cape Kidnappers (BRADFORD, et al., 1980) indicate inflowing and out-flowing waters and support the HB circulation pattern observed by RIDGWAY (1960). The two drogues deployed off the east Cape Kidnappers coast drifted south (BRADFORD, et al., 1980).

Later current experiments involved the use of seabed drifters (HANDS, 1987) and drogues. The drogues (two sets of two) had attached radio transmitters to enable positioning by triangulation from two receiver stations sited onshore. WHITE (1994) deployed sets of 50 drifters each along the 10 m isobath between Clifton and Marine Parade, early May 1990. The return rate of the attached finder information cards was good (least return was 54% and up to 90%). The drifters were found along the length of coast between Westshore and Cape Kidnappers. Interestingly the drifters found on the beach along Cape Kidnappers were where gullies exit the cliff-line, suggesting the gullies traverse the submarine rock platform.

The seabed drifter data indicates: -

1). Between the headlands (off Awatoto and Clive) the seabed drifter dispersion can be bidirectional (drifters travel either north or south) and shore parallel, with a drift towards both Scinde Island and Cape Kidnappers headlands.

2). Drift can be unidirectional, off Marine Parade, and to the south. Towards the south was also the preferred direction of bidirectional dispersion.

3). In the lee (updrift side) of the headlands the nearshore drift is onshore, across the shallowest bathymetry. This could be some function of swell wave refraction about "adjacent headlands, causing the wave spectrum to narrow after the elimination of high frequency components in the offshore swell" (BLACK and VINCENT, 2001).

4). Drifter time of travel, between release and find was variable, between same day (off Westshore) to 3 months when found in a fishing trawler net in northern HB. Generally, the drifters traveled some 200 m to 3000 m per day, with increased rate in the winter.

Experiments with Radio Drogues.

Two sets of drogues were deployed, with the first set in 1988 (unpublished data, WHITE) and the second in 1990 (WHITE, 1994). Each deployment took place at the seaward buoy marking the Hastings District Councils' sewage outfall diffuser off Clive (Figure 2.3). The effective depth of these drogues was set at 5 m (the early drogues were a vertical cylinder design whilst the second set were a subsurface plane sail).

Data showed two results, firstly an early drift path, and secondly a later divergence. The early drift path of both sets of drogues followed a similar direction to that observed by RIDGWAY (1960) of a current exiting HB off Cape Kidnappers.

However, the sea conditions were different during the experiments and this produced some divergence of drift paths. During the first drogue deployment a southerly swell arose and on reaching exposed waters beyond the Cape Kidnappers the drogues turned from east to a north west direction and passed Napier (two hours later) and then both radio tracking signals were lost. This is a speed of some 46 cm/s.

The second set of drogues exited HB by rounding Cape Kidnappers and moved south similar to BRADFORD, et al. (1980), they then turned from south to an east direction; later the radio signals were lost. These two drogues traveled at about 2 km per day, or at some 2 cm/s.

In both drogue experiments, the drogues traveled mostly in parallel trajectories, suggesting no large-scale eddy flow that would separate the two drogues. Drogue trajectories in the lee of Cape Kidnappers suggest a tidal component. Only in the latter stages of the second deployment whilst off the Cape did the two drogues take on differing paths with trajectories suggesting differing circulation.

In summary along the length of the field site coast, Clifton to Marine Parade, the directions of current flow are: -

1). Nearshore to the south, (water depths greater than 10 m) and

2). Inshore to the north (water depths less than 10 m).

3). There is evidence of inshore-nearshore water circulation patterns off Clive and Westshore.

4). Generally the currents both nearshore and inshore are too weak to transport gravels, but in times of high energy, and associated wave activity then gravels could be transported.

2.6 Conclusions.

Hawke Bay is a large embayment (some 2,000 km^2) on the east coast of the North Island, New Zealand.

The southern coastal margin is characterised by a MSG barrier extending between salient headlands. This study focuses upon a MSG barrier length of some 20 km extending from the southern main headland of Cape Kidnappers (Late Pleistocene, Castlecliffian, (KINGMA, 1971) tephra, muds, lignites, conglomerates, sandstones) to about Scinde Island (Early Pleistocene, Nukumaruan, coquina limestones (KINGMA, 1971)). The barrier rests on bedrock at the headlands, but rests on muds some 30 m thick representing continuous Holocene deposition between these headlands.

Geological evidence places HB on a subducting plate margin, (HULL, 1986, 1990) with accompanying tectonic activity that is ongoing with evidential Holocene co-seismic downwarping and tsunami (HULL, 1990; CHAGUÉ-GOFF, et al., 2002). Most recently, in 1931 the Napier earthquake uplifted the Scinde Island by +1.8 m whilst the Haumoana area downwarped -0.76 m (about Mean Sea Level). The subsidence at the Tukituki River inlet may have changed the river gradient and subsequently the textural sizes supplied to the coast to a coarser bed load. The local HB Holocene sea level curve shows an increase of sea level with possible still stands and oscillations (SL was periodically transgressive or regressive) to some 6,000 y BP and possible as late as 1,200 y when SL stood at +5.0 m aMSL (BROWN and GIBBS, 1996).

The main barrier physiographic components are: -

1). The ridges which can be multiple crested (Holocene) and sub-parallel to the modern shore,

2). The contemporary (modern) single crest transgressive barrier.

The textural gravels are dominated by hard greywacke clasts (HEMMINGSEN, 2000). The greywacke clasts can be derived from either the Cape Kidnappers cliffs (length 4 km; height 100 m), or from the Tukituki or Maraetotora Rivers. Over the sampling period the river discharge gravel population was negligible. Beach samples in this study therefore represent a quiet period of the HB barrier evolution with gravels supplied via Cape Kidnappers conglomerates, and/or reworking of the population across the swash active beachface.

Climatic data from Napier Airport (from 1949 to 1984) indicates the dominant wind direction is the south quadrant with summer easterly (onshore) winds. Strong winds (strong wind > 10 m/s) are generally from the southeast or in winter from the northeast (WHITE, 1994). It is also from the northeast that ex-tropical cyclonic weather patterns arrive which travel down the east coast (STEPHENSON and SHULMEISTER, 1999) accompanied by high rainfall and low atmospheric pressure. As winds approach speeds of 5 m/s the inshore swell waves crest spill (white caps). If the wind persists short period, low wave height (T_b = 3 s; H_b =0 .2 m to 0.3 m) wind waves are generated inshore, but these seldom transgress the beachface swash zone, instead they break with the swell waves at the beachface step. Having a wave breaker line at a step facilitates a more consistent estimate of the hydrodynamics and as a measure of wave steepness, as a morphodynamic parameter.

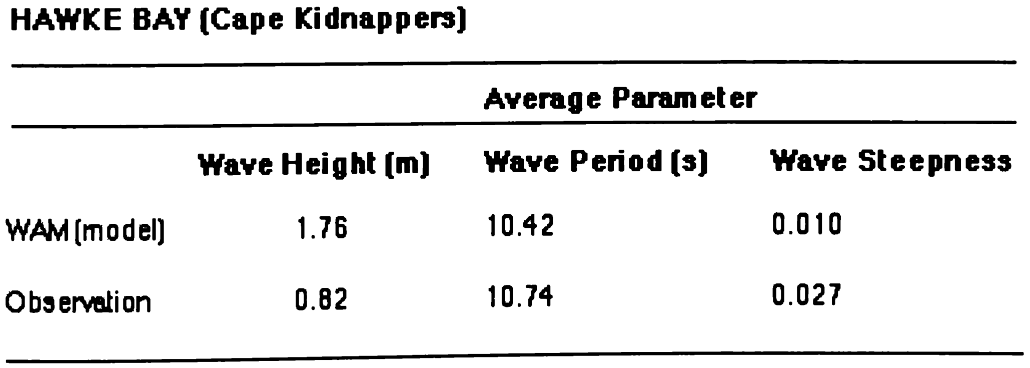
Coastal storm records since 1810 indicate a period of high frequency high seas events in the late 1800's to early 1900's and a subsequent gradual decline until an outlier increase in the 1960 to 1970s and decrease till present (SMITH, 1984; STEPHENSON and SHULMEISTER, 1999; PAGE, et al., 1994; NAPIER TELEGRAPH). This suggests that the contemporary barrier is in a general low storm frequency state with no large or frequent storm events either impacting the contemporary transgressive ridge, or rain storm events that can deposit large quantities of sediment into the inshore from the gravel supply rivers (Tukituki River inlet at Haumoana or the Maraetotora River inlet at Te Awanga). This suggests that the HB barrier may be in a low energy state of evolution.

Hydrodynamically the HB tidal range is micro-tidal (2.0 m maximum spring tide) about a MSL established at the Napier port (NEW ZEALAND NAUTICAL ALMANAC, 1998-1999). Bathymetrically the HB can be divided into the inshore and nearshore at the 10 m isobath. Isobaths are irregular are there are both charted and uncharted reefs. The 10 m isobath characterises the inshore into two submarine topographies, firstly into wide (2 km +) rocky submarine platforms to the north of both headlands, and secondly the narrower inshore with deeper waters off the barrier to the south of Scinde Island and off Marine Parade (NZ 56). The narrower inshore deeper water allows greater wave energy to impinge onto the Marine Parade beach, to become the relatively high-energy beach, especially when compared to Clifton.

Recent hydrodynamic wave parameters (ANDREWS, et al., 2003) from a WAM model and observed beachface wave break (WHITE 1997 to 2001) have polymodal frequency distributions and can have outlier frequencies. The average WAM model wave parameters based upon wind hindcasting between 1979 to 1998, and the observed wave break parameters (at Te Awanga Hall, 1997 to 2001), are summarised in Table 2.1.

The dominant incident swell wave direction is from the south, and these waves can enter HB by refraction about Cape Kidnappers (GIBB, 1962) and it is thought this can induce longshore currents and transport sediments towards the north (RIDGWAY, 1962).

Generally, observations show an evident longshore wave energy gradient, from a relatively low wave energy Clifton to a high wave energy beach at the northern, Marine Parade.



HAWKE BAY (Cape Kidnappers)

	Average Parameter		
	Wave Height (m)	Wave Period (s)	Wave Steepness
WAM (model)	1.76	10.42	0.010
Observation	0.82	10.74	0.027

Table 2.1 Summary of southern Hawke Bay wave parameters, wave height (m), period (s) and wave steepness from a WAM (deep water) hindcast model (ANDREWS, et al., 2003) and field observations of the wave breaker (WHITE, 1997 to 2001).

Water currents in HB range from the large-scale Oceanic currents (RIDGWAY, 1960) identified as (from the south) a cold Southland current and (from the north) a warm East Cape current (HEATH, 1975). These currents can combine and enter the HB flowing to the west along a central axis. Near the coast, the axial current divides with a north flow, which exits HB about Mahia Peninsula, and a south flow, which exits the HB about Cape Kidnappers. In southern HB, there is a general south flow in the nearshore waters, whereas the inshore waters flow north. These opposing water flows may induct smaller water circulation cells (gyres) for example off Clive (RIDGWAY, 1962) and Westshore (McCOMB, 2001).

The north flow of inshore waters could be counter current flow, but there is also a component of incident wave refraction. Generally, water current flow is too low to transport gravel sizes, however in high seas (wave height 4 m) currents can attain some 40 cm/s and this may assist in gravel transport within in inshore waters, in these instances the residual flow within the sheltered waters of Cape Kidnappers is onshore (south-east).

CHAPTER 3 THE PHYSICAL CHARACTERISTICS OF THE MIXED SAND AND GRAVEL BARRIER FIELD SITES.

3.1 Introduction.

Each site at the southern HB MSG barrier selected for study and sampling represents a stage of the FORBES, et al. (1995) morphodynamic evolutionary model. The FORBES, et a. (1995) model is used to characterise the morphodynamic evolution of Canadian MSG beaches and this Chapter aims to reflect the FORBES, et al. (1995) classification onto HB. For HB the morphogenic conditions are: -

1). Sites have a well-defined sediment (gravel) supply, and a sediment sink. The southern HB barrier has a well-defined supply of gravels (Cape Kidnappers cliff) and a sink (at Marine Parade, Scinde Island).

2). Sites range from lower energy wave (Clifton) to higher energy (Marine Parade) with intermediate energy at Te Awanga and Haumoana.

3). The FORBES, et al. (1995) model suggests four barrier states Figure 3.1: -

SO	Barrier initiation from a point (discrete) or line supply into a swash or drift (DO) proto-barrier and can depend upon local topography (bathymetry and coastal "backbarrier accommodation space" (FORBES, et al., 1995).
S1	Good sediment supply in shallow water, "basement geometry and headland spacing, ratio of accommodation space and sediment supply, proportion of sand to gravel, tidal exchange and backbarrier drainage, and morphodynamic feed-back within the barrier- nearshore system among other factors" (FORBES, et al., 1995).
S2	"Transition to a single ridge (S2) barrier may be effected by sea-level rise, self-cannibalism, or a combination of the two" (FORBES, et al., 1995).
S3	"Transition from stable (S2) barriers to unstable migrating (S3) structures are believed to be initiated in many cases by catastrophic remodeling of vulnerable systems" (FORBES, et al., 1995). This state could be described as remo-morphodynamics where the compensatory morphodynamics are in response to being remote from the established sediment source.
S4	The final stage is a fringing barrier with small backbarrier accommodation, though to occur where the barrier has failed or stretched and "drift aligned lengths have lost their seaward anchor, dissipative lag shoals, sometimes in the form of shore-normal gravel ridges" and these morphologies can influence the stranded beach (FORBES, et al., 1995)

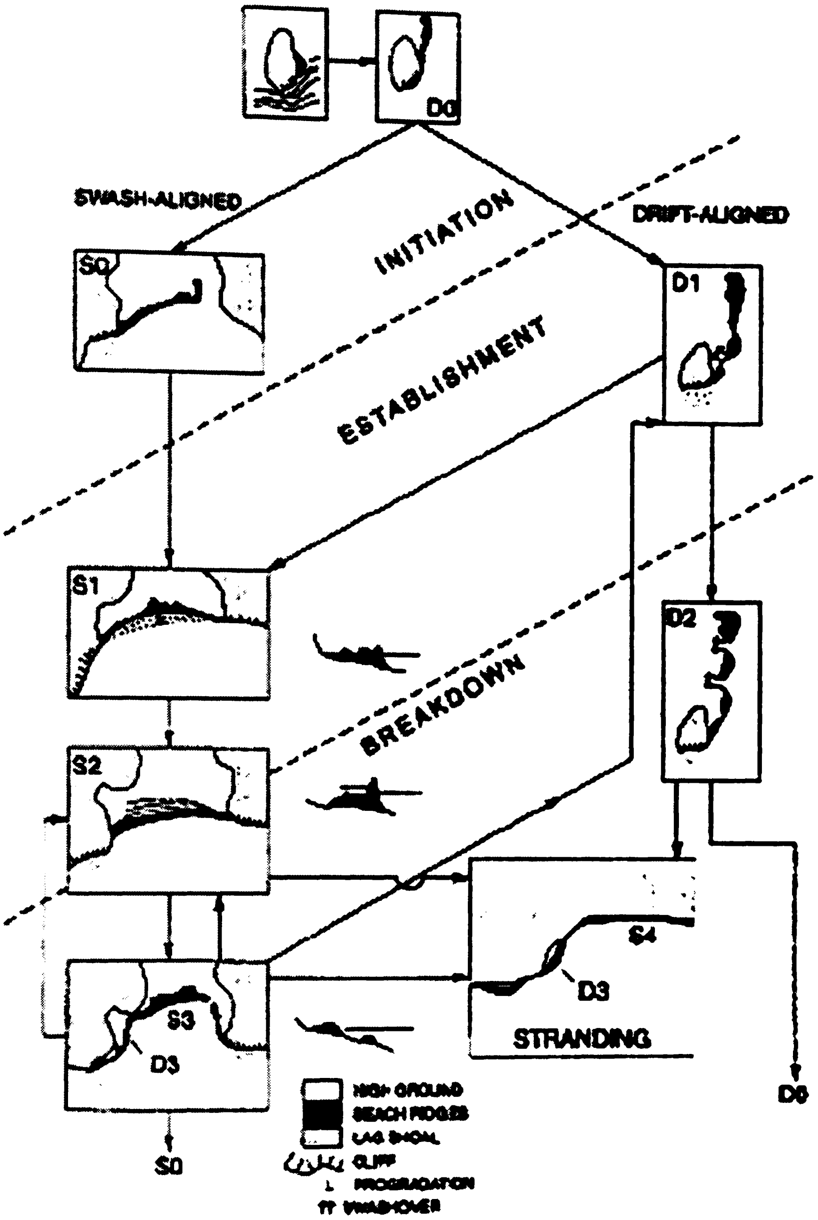


Figure 3.1. "Evolutionary typology for gravel barriers on a paraglacial coast undergoing transgression". (FORBES ,et al., 1995).

3.2 Field Sites.

From Cape Kidnappers to the north (Figure 4.7) the five sites are: -

i). Clifton.

Te Awanga, with two sites,

ii) Te Awanga Hall and iii) K2.

iv). Haumoana, and

v). Marine Parade.

Clifton.

(John White print 14)

Figure 3.2 Clifton, 10 April 2002, low water 1007. Exposed in the sandy swash zone beachface is bedrock. The bedrock is Castlecliffian (?) blue-grey siltstone and has cross-shore rills (0.2 m wide, 0.15 m deep) possibly from previous exposure to scouring. Similar rills occur on the modern submarine platform, off Cape Kidnappers. The siltstone shows piddock borings indicating water depths < 8 m at time of scouring. At the HW is a terrace cut, the fines have winnowed leaving a residual lag of medium size very well sorted gravels.

This site is swash aligned, has relatively low wave energy, is close to the sediment supply (Figure 3.4) of Cape Kidnappers and is an eroding barrier, Figures 3.2 and 3.3.

The sample site is characterised by a bedrock basement, Figure 3.2, whilst the overburden comprise mixed sand and gravel sediments. This basement is a fixed bed that can constrain the sediment available for transport.

There are two main morphological components to this site, firstly, a Late Holocene relict morphology, (multiple barrier crests), and secondly, immediately to the north is a 'modern' single barrier crest. The backbeach Late Holocene multiple barrier crest morphology is sub-parallel to the modern shore. To the north of the observation site, the beachface morphology changes abruptly to an actively transgressive single crest barrier that has overstepped a recent marsh complete with a 'fossil' (iron stained) sheep skull Figure 3.3.

Two (gravelly) sediment transport populations can be recognised, namely an alongshore population derived from the Cape Kidnappers colluvium supply, also found at Te Awanga; and 'cannibalistic' populations of Late Holocene material, found especially downdrift from Dan's Nose, Clifton, ranging in sizes and composition. For example, armoured mud balls (cobble sized, composed of lacustrine muds with an armour coating of 1 cm diameter pebbles) occurred in Te Awanga following the high seas of 4 April 2002.

(John White print 4)

*Figure 3.3 Clifton (Dan's Nose), 24 September 2000, at low water 0741. An exposed overstepped marsh containing 'relict' in situ material. The marsh formed landward of the transgressive single crest barrier. Now the single crest barrier is behind the observer. Across the swash zone the relict material is an exhumed marsh, with patchy and resistant to erosion clumps of rush plant roots (**A**), an iron stained sheep skull (**B**), and lag gravels embedded in the softer muds (**C**).*

The observation site, Figure 3.4, can overwash, for example 16 March 2003 (when the first 'flood hazard' signs were erected by local government). In Figure 3.4, the recent deposits of gravels can be seen by the heavy vehicle tracks. The site is 'downdrift' from the sea defenses at the Camp Ground and Fishing Club and a concrete rubble seawall in Figure 3.4.

Morphodynamic evolution stage (classification of FORBES, et al., 1995) of Clifton is here termed *initiation, swash aligned SO*.

(John White print 3)

Figure 3.4 Clifton sample site, 10 May 1998, at low water 1115. The sampling sites for the textural gravels and cross-shore transverse profiles. The sampling positions for the gravels are the low water cusp horns, the high water swash zenith. The topographic cross-shore transverse profile line ran across the beach on a line just beyond the front of the tonka-toy on the beach crest. At the near headland is the Cape Kidnappers cliff-line that extends into the distance, whilst in the shallows is a reef. The concrete rubble seawall defense across the beach crest is clearly visible. This seawall protects the access road into campsite in the distance. The sediment transport direction is to the north and towards the observer.

Te Awanga Hall.

The beach at Te Awanga Hall is a swash aligned with two, perhaps four supplies': -

1). Clasts from the Cape Kidnappers with characteristic clast surface iron staining and fragments of Castlecliffian conglomerates.

2). Gravel injected into the nearshore from the Maraetotora River flood discharge.

3). Clasts washed ashore from the inshore submarine rock platform, and the Te Awanga reef, off the distant headland point (Figure 3.5). These clasts typically have white, or pink, Bryozoan coatings, and can have kelp seaweed attached.

4). Gravels reworked from the beachface (cannibalism).

The Te Awanga gravel deposits (Holocene and contemporary) may, like at Clifton, also rest upon bedrock given the proximity of the reef and the inshore submarine rock platform. Morphodynamic evolution stage (FORBES, et al., 1995) of the Te Awanga Hall beach is *initiation-established swash aligned SO-S1.*

(John White print 13)

Figure 3.5 Te Awanga Hall, 28 June 2002, low water 1410. In the right foreground is the Te Awanga Hall seawall and mid way across the beachface are rail irons. Off the point, distal right headland is the Te Awanga reef. The Maraetotora inlet usually migrates over the beach towards the observer. Vegetation is early established on the upper swash beachface below the seawall. A high seas run-up seaweed strandline is visible between the vegetation (ice plants) and rail irons. Sediment (gravel sizes) transport direction is to the observers left (towards the north and Scinde Island).

The Maraetotora inlet can discharge gravel-sized sediments estimated as some 200 m^3 to 300 m^3 in a single rainstorm event. Historically this beachface has undergone irregular disturbances for local gravel mining for construction and erosion defense (rail irons) and the interference is increasing.

Te Awanga, K2.

This is a sediment transport swash aligned beach (Figure 3.6) where the barrier is transgressive. At the start of sampling in 1987 (WHITE, 1988) this was the most human-impacted beachface with a rail iron and tyre seawall and dense vehicle use, concentrated because of restricted access between dwellings and along the narrowing beach crest.

In historical time, from this site, a fishing boat was launched and recovered, with remains of the boat trailer in the beachface. Compared to Marine Parade Figure 3.8, K2 is a very narrow and morphologically compressed beach.

Morphodynamic evolution stage (FORBES, et al., 1995) of the Te Awanga K2 beach is *established swash aligned S1.*

(John White print 17)

Figure 3.6 Te Awanga K2, 28 June 2002, low water 1410. View down the cross-shore transverse profile line, in fact the yellow measuring rope crosses the beach just right of centre. Longshore transport is from the observers right to left. K2 has a cannibalistic beachface. Rail irons are emplaced in a double row configuration and with vehicle tyres. Note the high strand seaweed, and overtop deposition to the left at the run-up zenith. These strand lines are arcuate in plan view, whereas at Te Awanga Hall they are continuous and sub-parallel to the shoreline. These differences possibly result from swash interruption by the semi-pervious tyre seawall. Compare to Figure 3.8 for the beach width and the greater spatial arrangement of the beachface morphology.

Haumoana.

Haumoana is a sediment transport swash aligned, moderate energy, transgressive beach, (Figure 3.7). This beach was relatively long and unobstructed, and during this research period the gravelly sediments likely came from the Cape Kidnappers and the updrift cannibalism of the Late Holocene MSG barrier. The barrier at the sample site was actively transgressive and in a rollover state with frequent overwash sediment deposition producing a landward lobate morphology that buried an access road. This suggested an overall low sediment supply.

Soon after the cross-shore transverse profile sampling began the HBRC built a groyne with concrete tetrapods, 30 tonne units from the Napier port. This structure acted as an effective sediment trap for longshore MSG sediments (WHITE and HEALY, 2000). Over the period of data collection the Tukituki River mouth migrated but remained at least 150 m to the north and the gravel supply was, and fortunately remained, negligible, with no large-scale discharge events. Hence, the data in this study reflects the inter-relationships of the marine hydrodynamic and beachface morphodynamics

Morphodynamic evolution stage (FORBES, et al., 1995) of the Haumoana beach is *established S1. Possibly was breakdown S 3.*

(John White print 18)

Figure 3.7 Haumoana, 28 June 2002, at low water 1410. The view is down the cross-shore transverse profile line at the updrift side of the Haumoana groyne. The groyne is to the left and the net sediment transport is towards the groyne. The plunging wave break is beyond the tip of the groyne suggesting a sediment platform off the groyne tip and sediment bypassing. On the 4 April 2002, high seas caused gravels to overwash the groyne near the beach crest, transporting from left to right. The stranded tree stump is located on gravels deposited at the groyne overwash.

Marine Parade, Scinde Island, Napier.

Marine Parade is a sediment sink beach updrift of the gravel supplies (Figure 3.8) with the greatest travel distance from the gravel supply sites. It is swash aligned, and receives the highest wave energy of any part of the southern HB barrier.

Marine Parade represents an accretional beach (GIBB, 1973), although before the 1931 Napier earthquake overwash sedimentation occurred (Chapter 4, Figure 4.2). Because of its location at the end of a coastal compartment drift system the sediments should therefore reflect a maximum sorting of the gravel textural sizes, in terms of size and form with relatively narrow size and form ranges. The high wave energy should also produce the maximum profile bed height changes. This site has no 'operational' sea defense measures with the only 'disturbance' from a storm flood water pipe (approx 400 mm diameter) some 60 m to the south. Historically, an operational seawall defense was built, see Chapter 4, Figure 4.9.

Morphodynamic evolution stage (FORBES, et al., 1995) of the Marine Parade beach is *established S1*. However, Marine Parade may have changed from S2 to S1 (Figure 4.1 and 4.3) with the 1931 earthquake uplift.

(John White print 10)

Figure 3.8 Marine Parade, 27 June 2002, low water 0948. View down the cross-shore transverse profile line, the yellow measurement rope is visible across the beach in the photograph centre. There are three flights of post high seas event (4 April 2002) sediment deposition on the beachface. These deposits form a morphological tier of reworked (cuspate) ridges. The first reworked ridge is near the surveyor (MARK STUCKEY) on the beachface platform as a set of low water cusps. Across the mid beachface is a reworked (cuspate) HW ridge. In the immediate foreground is an overtop deposit from 4 April 2002. Compare this extended cross-shore morphology to Te Awanga K2, Figure 3.6 where the cross-shore morphology is compressed into a smaller cross-shore distance.

3.3 Summary and Conclusions.

The HB barrier has identifiable similarities to the model proposed by FORBES, et al. (1995) where these are "initiation", (for example Clifton), "establishment", (for example Te Awanga K2), and "breakdown" (for example Haumoana). The evolutionary model for the HB field sites, where all the sampled beaches are swash-aligned is: -

(i). Clifton	SO	initiation, sediment supply
and also	S3	transgressive, rollover, stretching, thinning and breaching.
(ii). Te Awanga Hall	S1	good sediment supply in shallow water. Backbarrier drainage and tidal exchange
and also	S2	single ridge, cannibalistic and may be affected by sea-level (SL) rise.
(iii). Te Awanga K2	S1	a sediment supply in shallow water.
and also	S2	single ridge, cannibalistic and SL.
(iv). Haumoana	S1	established
and also	S3	transition from stable to unstable barrier, remo-morphodynamics (remote from supply compensation).
(v). Marine Parade	S1	established, restricted accommodation space.
and also	S2	single ridge, cannibalistic and SL.

CHAPTER 4 THE FIELD AREA - A HISTORY OF COASTAL CHANGE AND HUMAN RESPONSES.

4.1 Introduction.

This chapter reviews the local Hawkes Bay historical records that detail the evolution of the Hawke Bay barrier since 1865. These include: -

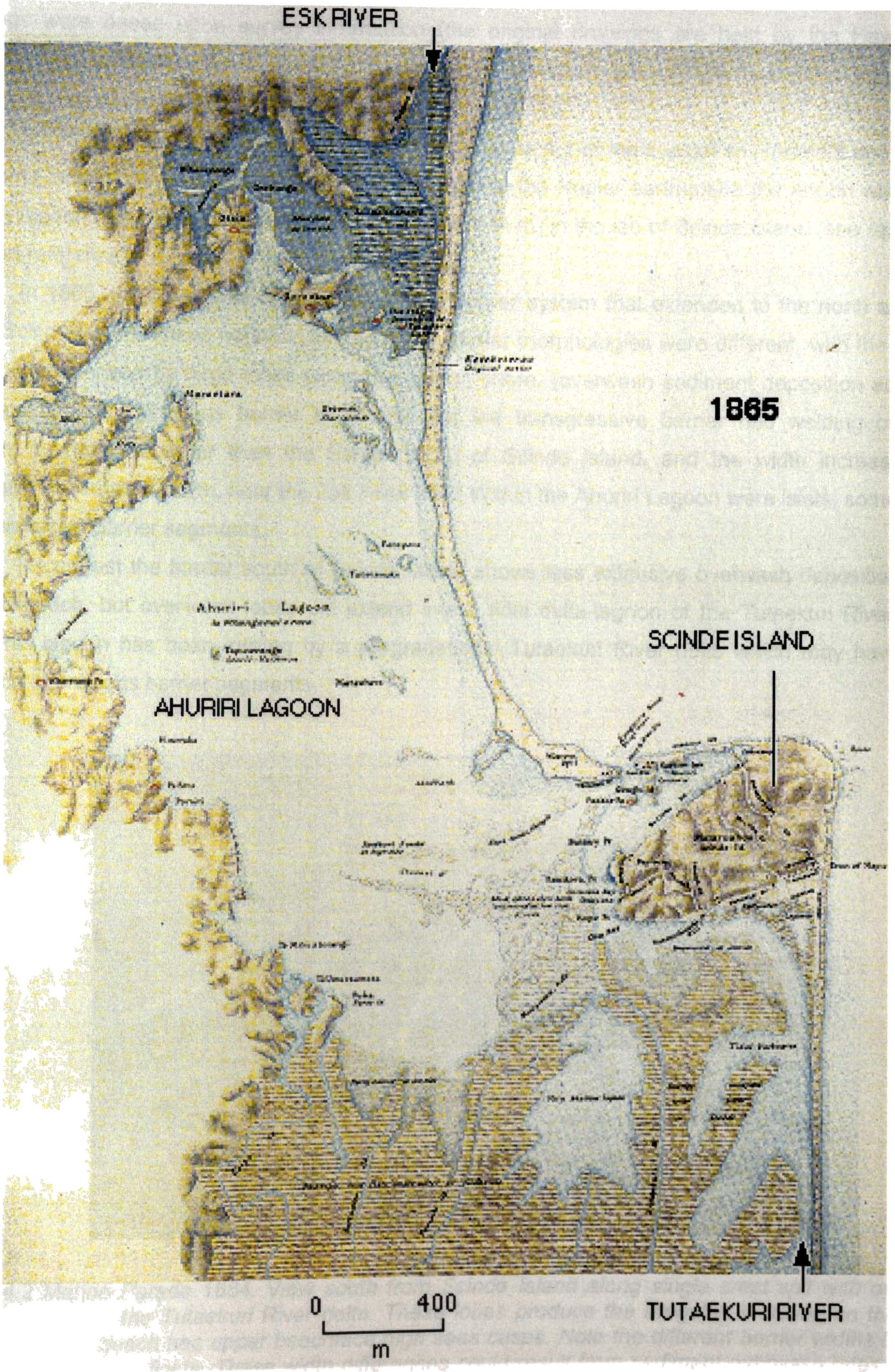
i) maps, based upon survey data, and photographic images;
ii) vertical air photographs;
iii) cross-shore transverse profiles;
iv) history of coastal development and defenses, and
v) a general history of coastal accretion and erosion.

4.2 Historical Records.

Coastline responses can be measured in terms of temporal and spatial alteration (DOLAN, et al., 1991, 1992), but the measurement of coastal response very much depends on the type of data. Over time, the methods of recording the HB coastal change have changed. Unfortunately, many records were destroyed in the fires following the 1931 Napier earthquake. There were three publicly available sources for coastal information in HB, namely the Hawkes Bay Museum and Hawkes Bay Cultural Trust, Department of Lands and Survey, and the Hawke's Bay Catchment Board and Regional Water Board. Of these the Department of Lands and Survey closed and the historical maps sent to Wellington to the National Archives, and the Hawke's Bay Catchment Board and Regional Water Board became the Hawke's Bay Regional Council (HBRC), who have archival records.

The first sketches of the coastal configuration, recorded soundings and composition of the seabed were recorded when Captain Cook visited. These records are at the National Archives, Kew, London. The Hawke's Bay Gazette mentions the commissioning of a bathymetry chart in 1837 for the entrance to the Ahuriri Lagoon, which was by then the port for the province. This chart was required because the Ahuriri inshore shoals shifted making navigation difficult. These inshore shoals continued to shift, so a solution was the construction, starting in 1876 of two long moles either side of a dredged navigable channel, to the Ahuriri Lagoon which allowed ease of navigable access (O'CALLAGHAN, 1986). Today the down drift mole remnant is patent by the skeletal poles on a boulder beach, (similar to Figure 1.3) whilst the up drift mole is obscured by longshore accretion and boulder armouring (Figure 1.2).

In the late 1880's, it was decided to move the commercial port to its present location by building off Scinde Island and across the submarine platform. Napier Port Ltd has hydrographic bathymetry charts from 1855 but these maps are confined to the local Ahuriri-Scinde Island inshore and nearshore. Records for the HB coast between Scinde Island and Cape Kidnappers are few, however, the HBRC has maps of East Clive (pers. comm., Brian Gestro) showing the coastal morphology as an echelon, shore parallel islets forming discontinuous barrier ridges.



(LESLIE REDWARD, Department of Lands and Survey, Napier).

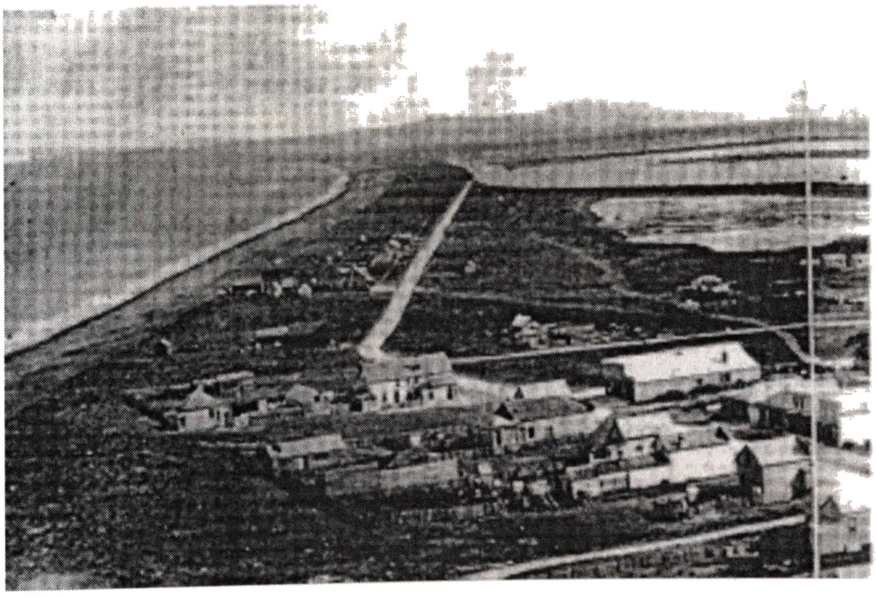
Figure 4.1 The Ahuriri Lagoon in 1865, depicting the coastal environment and morphology.

Figures 4.1 and 4.3 portray the Ahuriri estuary before (Figure 4.1) and after (Figure 4.3) the 1931 Napier earthquake (drawn by Mr. Leslie Redward, Department of Lands and Survey). These coloured drawings were based upon survey information (the original drawings are held by the Hawkes Bay Museum, Napier, Hawkes Bay Cultural Trust). Figure 4.2 is an early photograph taken from Scinde Island showing a view of the MSG barrier to the south.

Some general deductions can be drawn from Figure 4.1 of the coastal environment about Ahuriri and some indications of its evolution up to 1865. Prior to the Napier earthquake the Ahuriri was a large shallow lagoon (the deepest waters were some 12 feet (4 m) in the lee of Scinde Island (see Appendix 3 for chart reference).

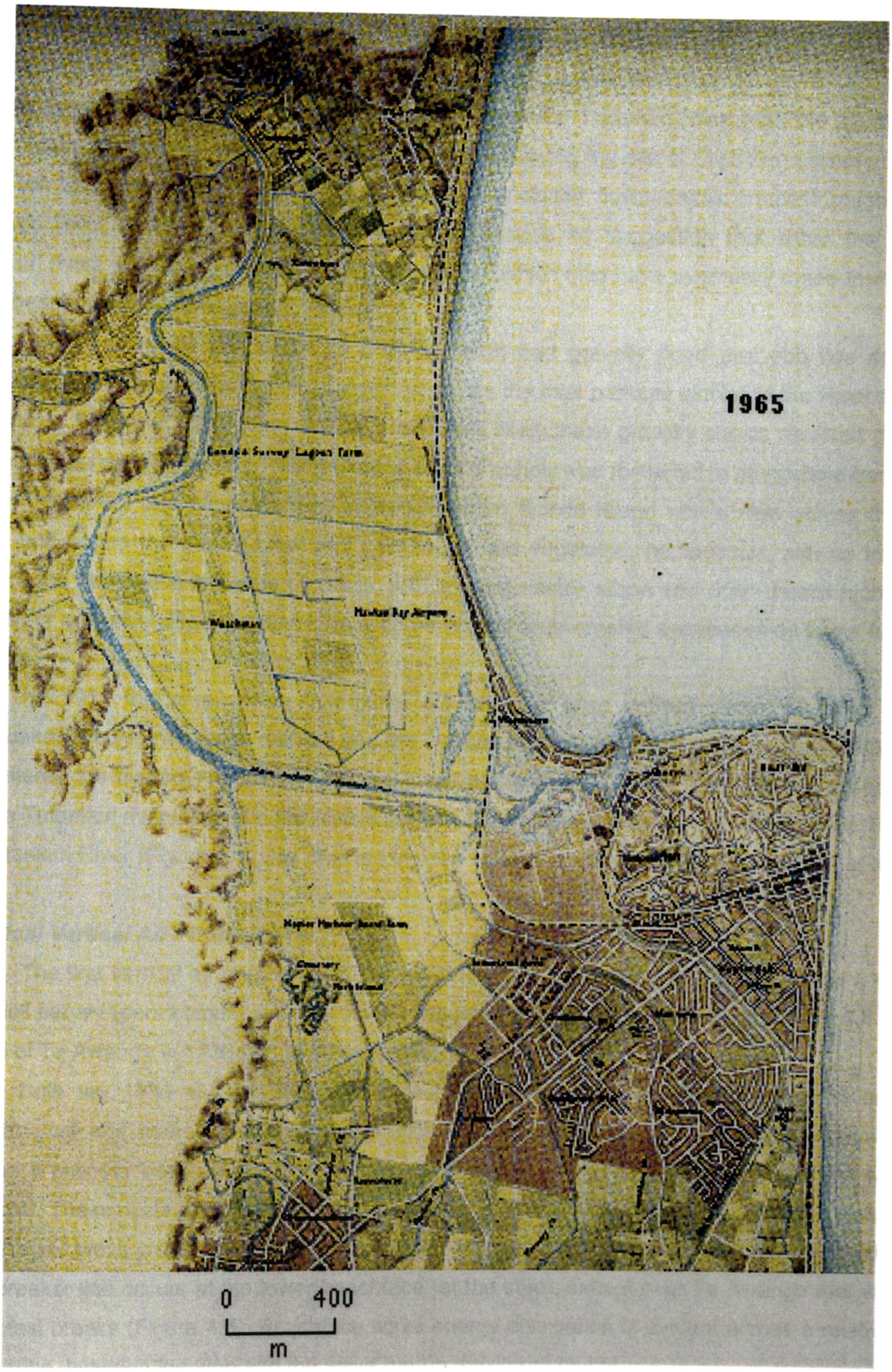
In 1865, the coast was characterised by a barrier system that extended to the north and south about Scinde Island. These northern and southern barrier morphologies were different, with the northern barrier characterised by large lobes along the lagoon shore, (overwash sediment deposition across the backbeach, and/or previous barrier segments that the transgressive barrier had welding onto. The northern barrier was wider than the barrier south of Scinde Island, and the width increases most noticeably towards the north, near the Esk River inlet. Within the Ahuriri Lagoon were islets, some shoals, perhaps former barrier segments.

In contrast the barrier south of Scinde Island shows less extensive overwash deposition across the backbeach, but overwash lobes did extend into a tidal delta-lagoon of the Tutaekuri River (Figure 4.2), This lagoon has been infilling by a progradational Tutaekuri River delta which may have buried evidence of previous barrier segments.



(Hawkes Bay Cultural Trust, negative 1987(a)

Figure 4.2 Marine Parade 1864. View south from Scinde Island along single crest spit with overwash lobes passing into the Tutaekuri River delta. These lobes produce the irregular shoreline on the inland water body. The beach has upper beachface high seas cusps. Note the different barrier widths between the near and far view fields. These width differences could result from sediment overwash rates, with an increase toward Scinde Island.



(LESLIE REDWARD, Department of Lands and Survey, Napier).

Figure 4.3 Ahuriri 1965. Reclaimed lagoon and no river inlets, and consequently a reduced flow through the tidal inlet and likely reduction of gravel recycling into the inshore by lagoonal discharge via the 'old' Ahuriri' inlet. Napier port is visible protruding into the inshore off northern Scinde Island.

There are some general observations on the associations between the morphology, the sediment textures, and the biology. For example in 1865 the northern barrier enclosed a tidally flushed lagoon with two river inlets, namely the Esk River from the north and the Tutaekuri River from the south. Both river inlets had muddy flats, and indeed there were crabs occupying the site of Crab Farm winery (NZMS 260, 1981, ref V21 432898). To the south, the barrier enclosed fluvial-deltaic muds through which the Tutaekuri River drained into the Ahuriri Lagoon. There is no suggestion that either the Esk or the Tutaekuri rivers supplied gravels to the Ahuriri lagoon, which may have eventually made their way to the active beach, or indeed the gravelly barrier.

The Ahuriri tidal inlet (west of Scinde Island) had gravelly flood and ebb tide delta shoals, suggesting that gravels could have transported across the inlet perhaps similar to the River Ore inlet, at Orfordness, Suffolk (KIDSON and CARR, 1959). It is likely these gravelly shoals received gravels from the alongshore drift, hence suggesting that the coastal supply was restricted to alongshore transport.

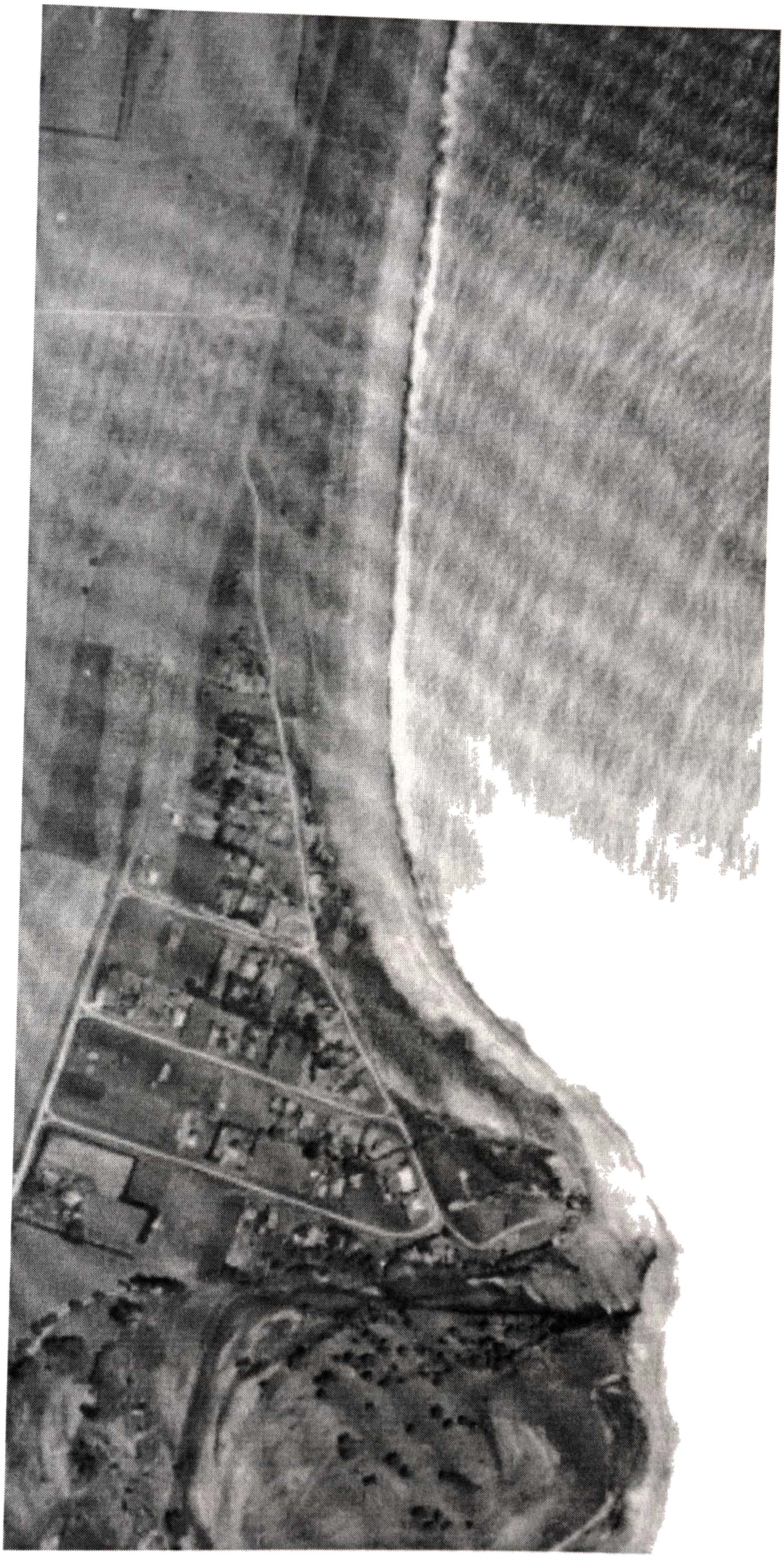
Figure 4.2 is a photograph taken in 1864 from Scinde Island with a view across the southern barrier and shows the barrier crest and backbeach was vegetated, herbaceous, with no trees, and to seaward the beachface had sets of cusps, with a recognisable storm and down beach high seas sets. The barrier is a wide single crested form, with no distinct multi-crested sequences as found further south at Clifton.

In 1931 the area shown in Figures 4.1 and 4.2 were uplifted some 1.8 m in the Napier earthquake. The Ahuriri lagoon drained and the inshore seabed shallowed (H.M.N.Z.S. VERONICA). The uplift altered the hydrodynamics and the sediment supply to the inshore, especially since both the Esk and the Tutaekuri river inlets into the Ahuriri Lagoon were diverted to the coast further afield. For example the Tutaekuri River (Figure 1.1) was diverted into the Ngaruroro River near Waitangi south of Napier.

Historical Vertical Air Photographs.

The first vertical air photographic survey of HB was undertaken in 1936 as part of a Heretaunga Plain soil survey (pers comm., Jim Watt) and included the southern HB coastline. Figure 4.4 and Figure 4.5 are of Te Awanga in 1936 and 1950 respectively.

Both the 1936 and the 1950 air photographs show the Te Awanga beach to have similar morphological and hydrodynamic characteristics. For example, the geomorphology common to both includes a cuspate beach crest, and cuspate HW ridges, and overwash lobes about the Maraetotora River inlet. These occur to both the north and south of the inlet. Hydrodynamic similarities include inshore incident swell wave crests that are oblique to the shore, suggesting longshore drift (to the north). A single wave breaker line occurs at the lower beachface (at the step), except over Te Awanga reef with multiple wave crest breaks (Figure 4.5). Beachface wave energy dissipation is evident across a relatively narrow swash zone, between the step and the wave run-up maximum height.



(NZ Aerial Mapping, Hastings)

Figure 4.4 Te Awanga, 1936. The first vertical aerial photograph of Te Awanga, that formed part of series for the soil mapping of the Heretaunga Plain. The Maraetotora River 'delta' forms the lower part the view, from the left of centre to the right where a narrow barrier crest truncates the delta. The narro barrier crest is the single crest transgressive ridge, that is welded onto the sub-parallel, multi-creste ridge sequence to the north of Te Awanga, observed as dark grey shore sub-parallel lines inland from th shore. Irregular overwash lobes to landward either side of the Maraetotora inlet.

(Hawkes Bay Regional Council)

Figure 4.5. Te Awanga, 1950. Examples of ongoing similar process of the beach morphodynamics typified by tiers of ridges, reworked as cusps and the prevailing incident wave pattern suggesting refraction of southerly swell, and longshore drift to the north (to observers left). A characteristic narrow breaker zone occurs as the darker grey at the shoreline. Note the narrower transgressive barrier between Clifton (to the right) and Te Awanga (to the left), compared to the wider multi-crested ridges of the antecedent barrier to the north (left) of Te Awanga.

Historical Cross-shore Transverse Profiles.

The Hawkes Bay Regional Council (HBRC) has a collection of profiles, starting in 1916 at a site on the Ahuriri barrier to the north of Westshore and the Hastings District Council (HDC) profiles start in 1914 at East Clive.

4.3 Summary and Discussion of the Historical Records of Coastal Evolution.

The historical records demonstrate a coastal evolution dominated by tectonic, and morphodynamic processes.

The response to the earthquake in 1931 was to change the base level relative to Mean Sea Level, (MSL). At the coast the base level change varied with +1.8 m uplift at Scinde Island and a -0.76 m subsidence at Haumoana (HULL, 1990). Base level change may have changed the fluvial supply in terms of rate of supply, and possibly the sediment textural variations. For example with a 0.76 m subsidence at the Tukituki River inlet the rived bed gradient towards the coast would have increased. The steeper gradient could increase the supply of sediments that may also have become coarser (Chapter 2). Two river systems, the Esk and the Tutaekuri ceased to supply sediments to the Ahuriri estuary.

Vertical air photographs for Te Awanga 1936 and 1950 indicate the planform coastal morphodynamic responses are similar at two separate time intervals. According to the historical storm information, (Chapter 2, Figure 2.5), there were no storms in either 1936, or 1950 so that the morphologic features depict some previous storm event(s). Despite the 14 y gap between the photographic records, there are strong morphological similarities, especially of the 'relict' stormy high seas morphologies. Relict morphologies have two distinctive storm characteristics, firstly the cuspate barrier crest and HW ridge, and secondly the backbeach overwash lobes. These can be observed north and downdrift of the Maraetotora River inlet and Te Awanga reef, especially where the beach shoreline configuration changes from a drift to a swash alignment.

Given that the Te Awanga Hall beach is transgressive then the air photograph suggests a morphodynamic process of ongoing overwash sediment deposition. This overwash process can also be seen in the early 1864 oblique photograph of Marine Parade from Scinde Island (Figure 4.2), so there is a spatial similarity of process across sites. It appears that the barrier beach is wider perhaps in the more actively transgressive lengths of the barrier, and is part of a beach width increase coincident with crest height reduction, as roll-over accelerates.

4.4 History of Coastal Development and Defenses.

Prior to 1855 the Ahuriri lagoon inlet changed from a northern position to one further to the south because of river flooding of the lagoon. The new inlet position was maintained by Maori people (GIBB, 1996). The present inlet (see Figure 4.1) is maintained by moles (Figure 1.2) and dredging. Subsequently there have been ongoing coastal defense measures, either for economic development (Ahuriri port mole construction) or in response to high seas events (an ad hoc societal response to an event). For example, groynes at East Clive were constructed to stabilise the Ngaruroro Lagoon inlet (HBRC).

An outline of the history of coastal works at each sample site (Figure 4.7) follows starting at Clifton in the south and north to Marine Parade. Appendix 4 has a sampling rational and contains the sampling site positions.

Clifton.

By the 1920's, Clifton had become a recreational reserve and frequented by summer holiday campers. Many such reserves were set up around New Zealand for WW 1 veterans and their economically destitute families. Defenses against erosion began soon after, for example, a groyne was successful at Clifton before 1939 (SMITH, 1984) near the Cape cliffs. The 1950's saw the erection of more permanent bach (summer holiday home) buildings. These baches were few, were on high ground at the base of the cliffs, and occupied initially only in summer.

The road into the camp passes along the beach crest and has eroded on several occasions whence the local farmer (GORDON family) ceded land to the camp for access. The ceding of land ceased and it became necessary to armour the beachface above which the road passed. The local government assisted with waste concrete and rubble supply over the years so that the modern 'seawall' forms a fixed

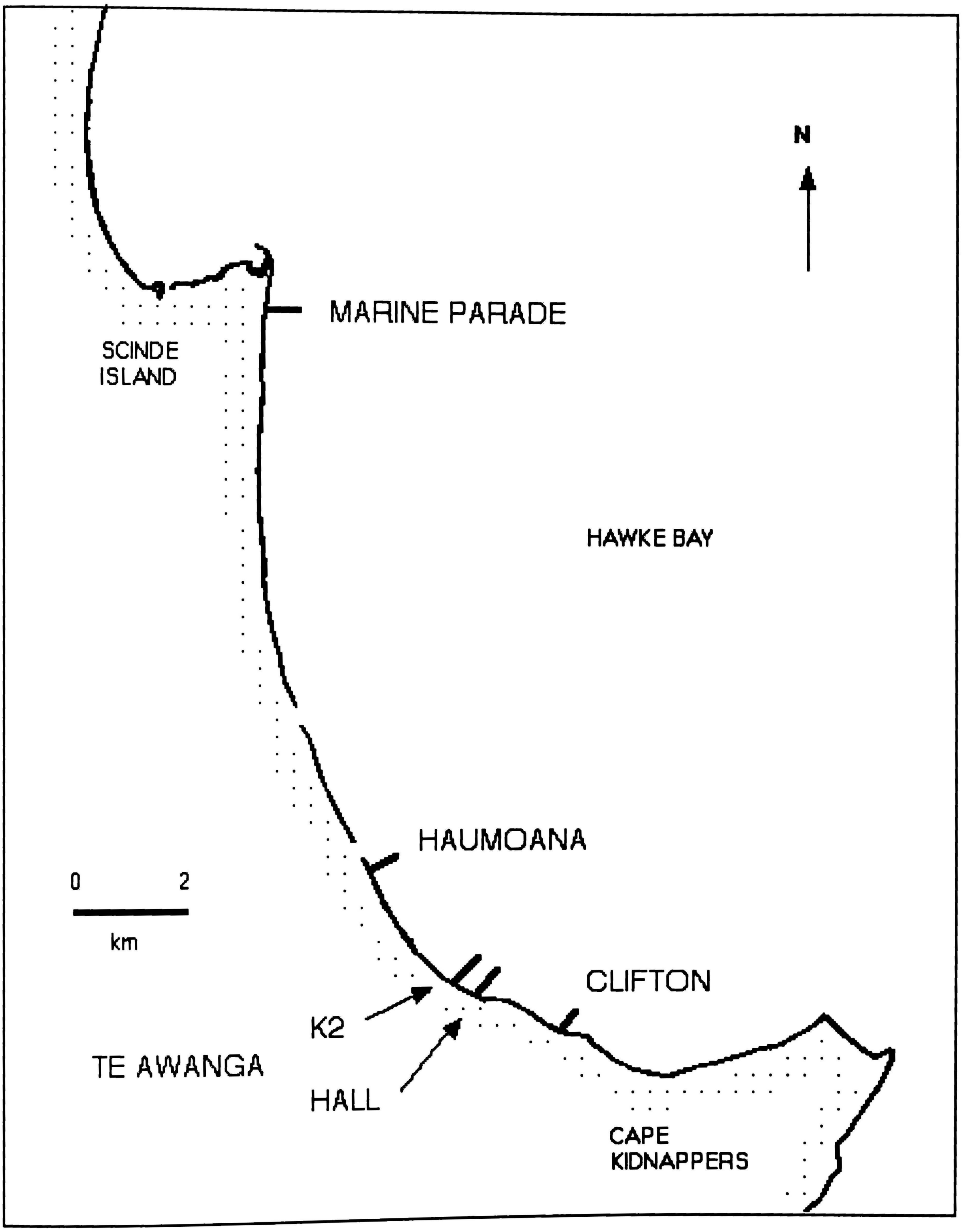


Figure 4.7 Location map, lines mark the historical coastal defense sites and the corresponding sampling sites for the textural gravel sizes and the cross-shore transverse profiles in southern Hawke Bay.

porous rubble seawall (Figures 3.2; 3.4 and 10.2). In recent time, the sea has undercut the seawall and 'potholes' appear in the road as it collapses.

Since the late 1980's, the sea has undercut the road that collapses by pot holing and overwash gravels deposit on the entry road. The camp site 'status' changed and caravans became permanent at the campground. In recent time, the permanent occupation of the caravans has increased. Over this same time period a fishing club began, and by the late 1980's a permanent 'club room' was built near the boat launching ramp which in the early 1990's was concreted from the HW ridge to landward. High seas in the 1990's overtopped the beach and as a result, the residents and club management armoured the beach crest using slabs of concrete, rail irons, tyres, and timber.

Since the mid 1990's, a second 'overflow' camp ground (to the north) became permanently occupied and a concrete (each 1 m^3) block seawall was built. Caravans from this site floated some 200 m inland and the concrete blocks transported some 50 m inland during high seas overwashing on 4 April 2002. This was reported on by the media. Since then, the reoccupation of the camp site has occurred and the concrete block seawall rebuilt.

Te Awanga.

Like Clifton, Te Awanga progressed through development from a camping ground, post World War 1, to increasingly permanent residential dwelling and as a housing satellite for Hastings and Napier. Te Awanga has extended to the north along the beach crest and inland to the fossil cliffs.

Coastal defenses began soon after the occupation of the land at the Maraetotora River inlet for a camp ground. Periodically the sea overtopped or the river water level increased so the first defenses were earth banks and ditches to drain the water (pers. comm., Ian Heaps). This camp area is presently at +1.8 m MSL. Recently (in 2002) at the Maraetotora River inlet and bounding the Camp site the HBRC constructed a river flood control stop bank that extends across the active beachface and this tends to disrupt overtop and overwash processes. To construct this stop bank material was strip-mined off the active beachface.

In the 1960's and in 1973 high seas produced overwash waters. Evidence of these and previous overwash sediment deposition in the form of gastropod shell material in gritty-sands is decernable in earthwork cuttings for roading and septic tanks within 150 m of the present beach crest. The local community took several defensive measures. These included: -

1). Rail irons that were driven (pile driver) into the beach along the front of Te Awanga (Chapter 3; Figures 3.5 and 3.6).

2). The seawall (concrete blocks, each about 1 $yard^3 = 0.7646\ m^3$) in front of Te Awanga Hall (Figure 3.5, foreground right).

3). A ditch dug and backfilled with clay to form an impervious berm bank, between the Hall and south to the Te Awanga Lagoon (some 160 m), and north to the first house (some 50 m) (pers. comm., John Osborne).

A second row of vertical rail irons was added fronting the beach crest houses to the north (Figure 3.6). This second row terminates at K2, and to the north, the rail irons revert to a single row that continues to the northern boundary of the Te Awanga housing. Also at K2, a sample site, (Figure 3.6), for cross-shore transverse profiles (the same site is also a HBRC cross-shore survey profile line referenced as HB 2) is the wreckage of a boat-launching trailer made from a truck chassis in the upper swash zone.

Beach access at K2 is confined between houses and in modern time the number and type of vehicles accessing the beachface has increased. These vehicles tend to force their way onto the lower beach through a narrow gap between the rail irons no matter what the physical state of the beachface.

Recently, (June 2003) the local government introduced 'beautification' as a method of erosion control. This entails covering the beach crest with soil and plants whilst effectively increasing the beach crest height. This 'method' also prevents run-up waters from percolating into the open fabric of the gravely beach crest. These beautifications were initially introduced to reduce the proximity of vehicles to beach crest houses. Consequently, the beach crest residents are now actively engaged in restricting and confining the vehicle access - except their own!

Haumoana.

Haumoana has a similar history of development and the increase of satellite residential housing. Initially housing was built along the seaward multicrest ridge with the single transgressive ridge to seaward, but also included houses built in a low area near the Tukituki River inlet. These low-lying houses were flooded on several occasions and eventually demolished and the area became a reserve. The sea front reserve was not developed into a camp site, consequently the perception of the need for defense against the seas was probably less than in Te Awanga.

(Gordon Bambry)

Figure 4.8 Haumoana, late 1960's. View to south with vegetated (Naio trees) barrier crest. In the foreground is a seaweed strewn HW ridge, in the mid-distance are defensive works (Stonehenge), and near the crest made of trucked in gravel.

Haumoana coastal protection began in the 1960's in response to a transgressive barrier overwashing into the sea front reserve (pers. comm., Gordon Bambry). Trucked in gravels were used to increase the barrier crest height, and concrete waste lengths were placed along the lower beachface (Figure 4.8). The tidal Tukituki inlet (WHITE, 1994) was a site of a bucket dragline dredge operation for shingle extraction (pers. comm., Gordon Bambry).

Since the early 1990's, the barrier at Haumoana began to migrate landward by overwash deposition a typical rollover process. Overwashing waters cut into and dissected the barrier crest and overwash gravels deposited as lobes to landward, burying the road and across into the domain reserve.

In early 1999, the HBRC built a groyne to protect a HBRC flood (river) pumping station and use the down-drift erosion to stabilise the Tukituki River inlet that tends to migrate north and towards the coastal protection stop banks built at East Clive (a low area). Beautification of the sea front domain reserve followed and the beachface traffic has correspondingly increased.

Marine Parade.

In historical time, Napier developed as a service centre for the surrounding province and constructed the largest coastal structure in HB, namely the port breakwaters.

A seawall was built at the turn of the century (1800-1900) along Marine Parade to protect the business district and courthouse and around the seaward base of Scinde Island (Figure 4.9) to protect the road to Hardings Road. This seawall may have been in response to more frequent high seas (Chapter 2, Figure 2.5) during the late 1800's. Marine Parade beach became a sediment sink on the updrift southern side of the newly established Napier port breakwater. The beach crest height, and possibly width, increased in the 1931 Napier earthquake, with a +1.8 m (MSL) vertical displacement.

(Hawkes Bay Cultural Trust Negative Number 7562 (g))

Figure 4.9. Marine Parade after the 1931 earthquake. View north, port seawall in far distance right. Irregular rocky shore uplifted 1.8 m. Seawall and promenade clearly visible in foreground.

Recently, (2003) the Napier City Council (NCC) started two schemes. Firstly, (NCC) dumped waste soil along the beach crest partially in response to overtopping high seas on 4 April 2002, but also as beautification using 'expressway' roading waste. Secondly NCC in conjunction with the local wine industry has for tourism, built a concrete pathway along the beach crest.

4.5 History of Erosion and Accretion in Southern Hawke Bay.

Most attention concerns erosion that for some lengths of coast appears to be an ongoing and a pervasive process. However, beach accumulation is reported, for example RIDGWAY (1962) observed gravel accumulated on the south side of shoreline structures at the Hastings District Council sewage short outfall, and at the Napier port breakwater.

The following sections briefly review the reports dealing with the changing southern HB barrier coastline.

Erosion and Accretion South of Scinde Island.

The two examples of coastal investigations for the south of Scinde Island coast are SMITH (1984) and GIBB (1973).

SMITH (1984) reports three beach monitoring programs for the beach from Scinde Island to Clifton.

1). 1939, following damage to the main State Highway at Waitangi, north of the Ngaruroro River inlet,
2) 1967-1968, a study of the southern HB coast by SMITH (1968, cited SMITH, 1984), and
3) 1974, a study aimed at understanding coastal processes and assessing the cost and feasibility of coastal protection.

SMITH (1984) notes that sites with a history of storm flooding and erosion are: -

1). Haumoana, with three known periods starting with erosion.
i). Flooding and sedimentation were experienced in 1938.
ii). The "Wahine" storm, 1968, resulted in deposition of overwash sediments. This process continued until 1984 (the report date). In 1968, erosion occurred almost back to the BM, after which accretion took place to some 26 m seaward of the former beach crest.
iii). There are variations of beach erosion and accretion for example between 1974 and 1978 the trend was for the beach to erode that changed in 1979 to accretion up until 1981 (winter).

2). Awatoto.
i). Erosion from 1939-1943.
ii). Awatoto accretion from 1943 to 1948; erosion from 1950 to 1954; accretion, from 1955 to 1975 (SMITH, 1984, Figure 10); erosion from 1975 to 1984.

3). North of Awatoto the erosion periods are: -
i). 1939 to 1948 minor fluctuations, with erosion in early 1950's; accretion from 1955 to 1984.

GIBB (1973) reports on a visit to southern HB following an erosive storm on 9 August 1973 and notes two main time frames of coastal erosional change, one short term and the second long term, based upon two vertical air photograph sets, 1936 and 1972.

GIBB (1973) suggests firstly that the short-term erosion occurs during short wave steep seas from the north-east quadrant, and accretion with long period swells from the southern quadrant, and secondly the steep seas are more frequent in summer, and the long period waves associated with accretion are more frequent in the winter.

Long-term shoreline history relates to the net coastal change between 1936 and 1972 at sites between Clifton and north of Awatoto. Figure 4.10 reflects the GIBB (1973) data and indicates the net erosion or accretion along the coast from Clifton to Awatoto between 1936 and 1972.

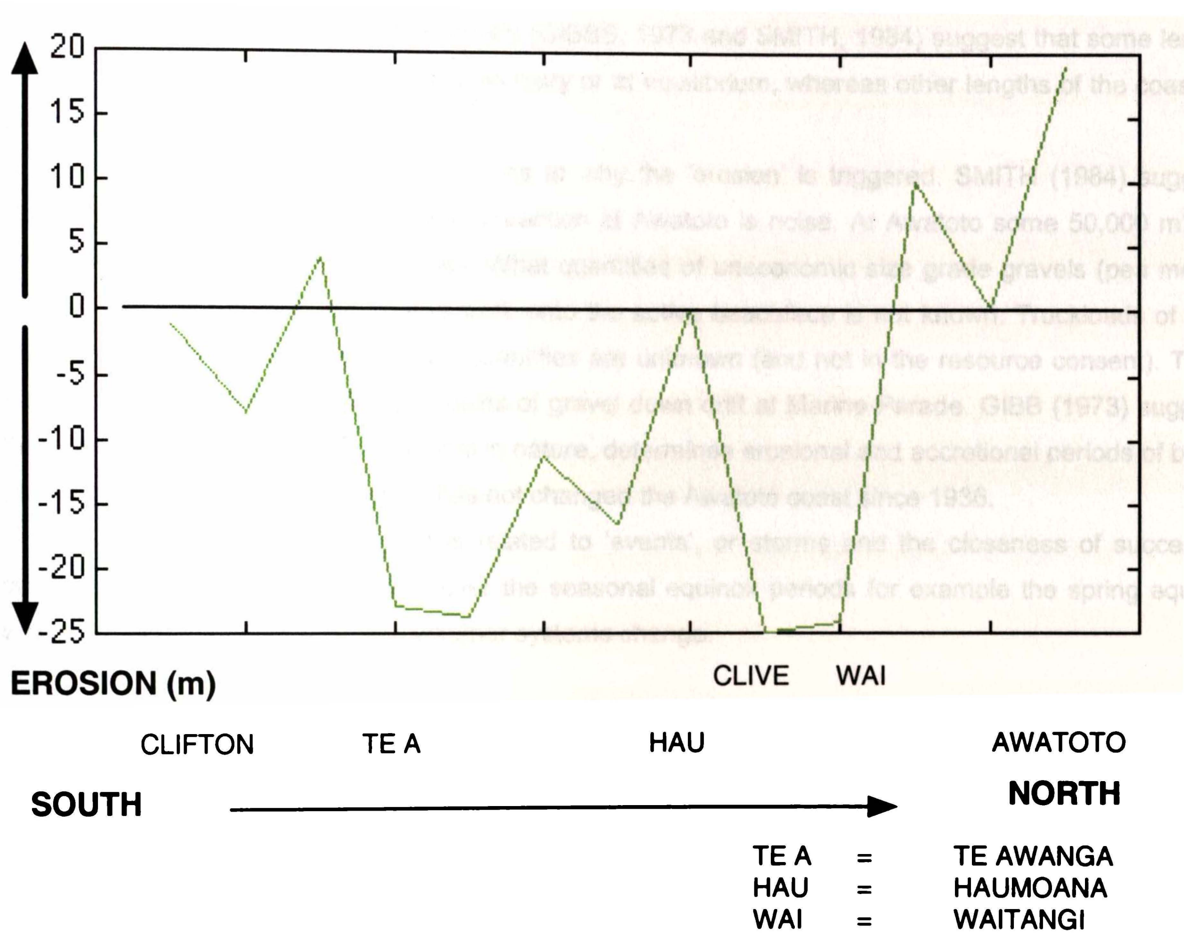


Figure 4.10. Southern Hawke Bay, the relative shoreline change between 1936 and 1972 (based upon data in GIBB 1973). The shoreline change is a measure of a horizontal distance between the high water and a fixed point inland that is common in both the 1936 and the 1972 photographs. The changes of horizontal distance are i) no change (at 'equilibrium') or, ii) erosional, negative values (a decrease of the horizontal distance) or, iii) accretional positive values (an increase of the horizontal distance).

Discussion.

Historical records suggest that the barrier can change between an erosional and accretional phase at some transverse profile sites, for example Haumoana, but not at other sites, viz. at Clifton. At Clifton the beach erosion is an ongoing process (SMITH, 1984). Using vertical air photographic data and placing beaches into an erosional rank order, the greatest ongoing erosion sites are at East Clive and Waitangi, (for locations see Figure 1.1) followed by Te Awanga and Clifton (GIBB, 1973). SMITH (1984) suggests East Clive has sustained the greatest erosion.

North of Awatoto, the shore has tended to accrete, and south of Awatoto, the shore has eroded (SMITH, 1984; GIBB, 1973). Interestingly GIBB has no change or "equilibrium" sites at Haumoana (the groyne construction site in 1998) and at Awatoto.

SMITH (1984) suggests that most of the erosion or accretion occurs when the longshore transport of sediment is interrupted, for example by the construction of groynes (see Figure 1.4, downdrift, and Figure 3.7, up drift of the Haumoana groyne. GIBB (1973) concurred that groyne accretion will probably be great on the updrift side, with erosion on the down drift.

Erosion is usual at the time of large storms with a post storm accretion phase, but this latter phase is over a prolonged time (SMITH, 1984). East Clive, for example, appears to have suffered increasing erosion since 1973, and this appears to be because of the increasing frequency of storm waves overtopping the barrier. Both reports (GIBBS, 1973 and SMITH, 1984) suggest that some lengths of the coast may be more positionally stationary or at equilibrium, whereas other lengths of the coast are erosive and at various rates.

There are differences of opinion as to why the 'erosion' is triggered. SMITH (1984) suggests storms and structures, and that gravel extraction at Awatoto is noise. At Awatoto some 50,000 m^3/y of gravel is mined based upon gate sales. What quantities of uneconomic size grade gravels (pea metals, textural size some 8 mm) are poured back onto the active beachface is not known. Truckloads of sand are also removed from the beach and quantities are unknown (and not in the resource consent). These sizes could have some 'effect' on samples of gravel down drift at Marine Parade. GIBB (1973) suggests that the wave climate, which is seasonal in nature, determines erosional and accretional periods of beach processes and that gravel extraction has not changed the Awatoto coast since 1936.

It is likely the main erosion is related to 'events', or storms and the closeness of successive storms, where storms usually occur over the seasonal equinox periods for example the spring equinox when the winter-summer seasonal weather systems change.

4.6 Summary of Coastal Development, Defenses, Erosion, and Accretion in Southern Hawke Bay.

To the south of Scinde Island, the coast can erode or accrete with the most important influences thought to be storms and structures. This is true of structures that remain within the active beach zone, however, the Napier Marine Parade seawall that was uplifted 1.8 m in the Napier earthquake is now 'redundant'. There are also indications that coastal change may be a long-term process. For example, ongoing long trend response of the barrier is overwash and rollover especially the transgressive single crest barrier. Coastal response has both persistent and variable rates of change. Some coastal sites show a similar trend over periods of recorded time, for example GIBB (1973) reports no change at Awatoto and Haumoana between 1936 and 1972, but at Clifton and Clive there has been continuous erosion (SMITH, 1984).

Some lengths of coast were protected by artificially raising the beach crest, for example, following a storm surge and large overtop waves in July 1946 that flooded the road and rail between Awatoto and Napier (SMITH, 1984). SMITH (1984, p31) suggests, "The beach recovery in the vicinity of the artificial beach crest has been more rapid and more substantial than occurred under natural conditions." This is because overwash sedimentation is prevented and instead the potential overwash sediment is deposited and accumulates on the front of the barrier crest and forms a reservoir of material to act as a buffer during storm periods.

There is some evidence of seasonal responses, namely summer erosion associated with short steep north-east seas, and winter deposition with long period southern swell seas.

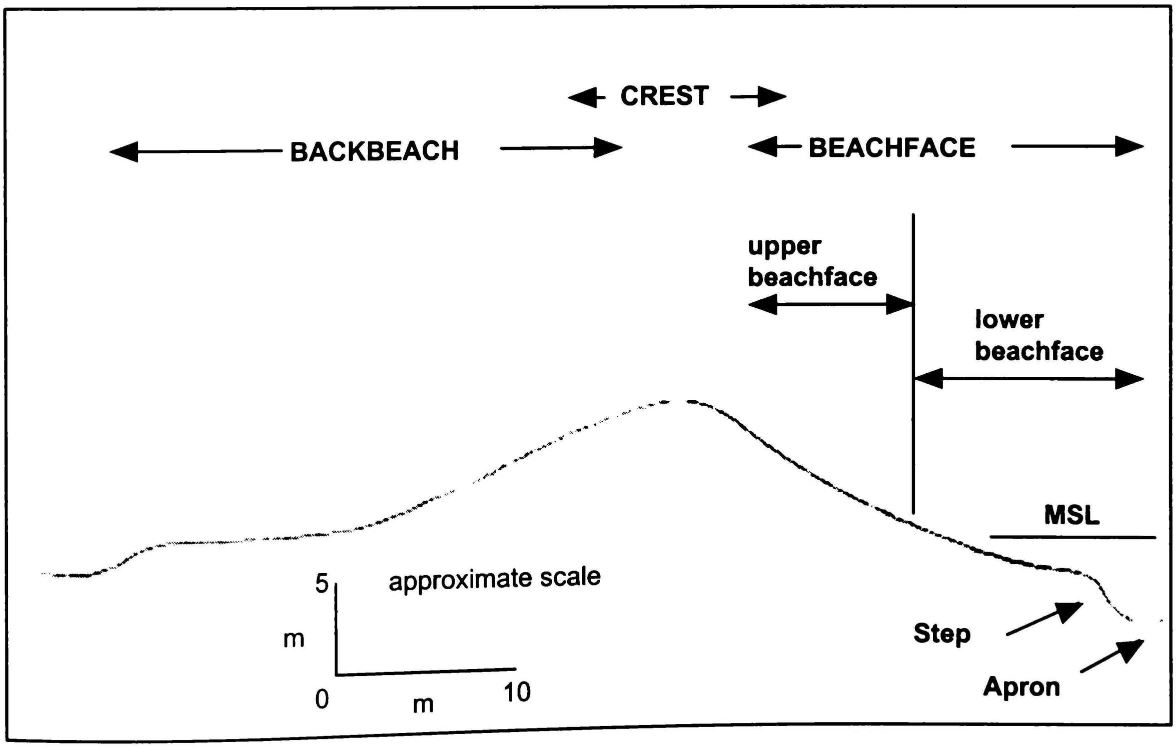
CHAPTER 5 THE BEACHFACE MORPHOLOGY AND IT'S RESPONSE TO VARIATIONS IN WAVE CHARACTERISTICS

5.1 INTRODUCTION.

This chapter defines firstly the Hawke Bay's beachface morphology and presents an outline of the morphodynamic processes that maintain the HB beach system. Secondly, three sets of photographs show the morphodynamic and hydrodynamic relationships that can be observed at the Te Awanga beachface. These photographic sets show the changes of the morphological features in response to 'wave' activity as (i) the tidal effects upon accretion and erosion, (ii) wave erosion and very early deposition and (iii) wave associated deposition.

5.2 The Hawke Bay MSG Barrier Beachface Morphology.

The HB barrier morphology has three main physical segments that on a transect from seaward to landward, are the beachface, the beach-crest and the backbeach (Figure 5.1). These morphological segments interface the HB hydrodynamic environment so there is a morphodynamic context and as such the wave steepness is an important hydrodynamic function for the formation and maintenance of a coarse grain (gravel) barrier beach crest (KING, 1959). Generally, beaches with coarse sediments are morphologically restricted to a few forms and SHORT (1979) suggests this is a function of (i) the coarse sediment and steep beachface relationship, and (ii) the reflective nature of the steep beachface to the incident waves.



MSL is mean sea level

Figure 5.1 The Hawke Bay contemporary barrier beach morphodynamic components. A cross section of typical Hawke Bay, transgressive single crest mixed sand and gravel barrier.

In this research, the MSL is the reference level for both the beach morphodynamics and the hydrodynamics. Further, the marine part of the coastal environment is referred to in the context of the breaking wave. Waves usually break inshore where this extends from MSL to a water depth of some 5 m. Seaward of the inshore is the nearshore to a water depth of 10 m. In the nearshore, storm waves can crest break viz. 200 – 300 m offshore and often wind waves crest break over the entire HB.

Cross Profile Morphology.

The contemporary HB single crested transgressive barrier ridge has three main segments: -

1). Beachface, the topographic slope facing seaward, divided about MSL into (1) a lower and (2) an upper beach, and

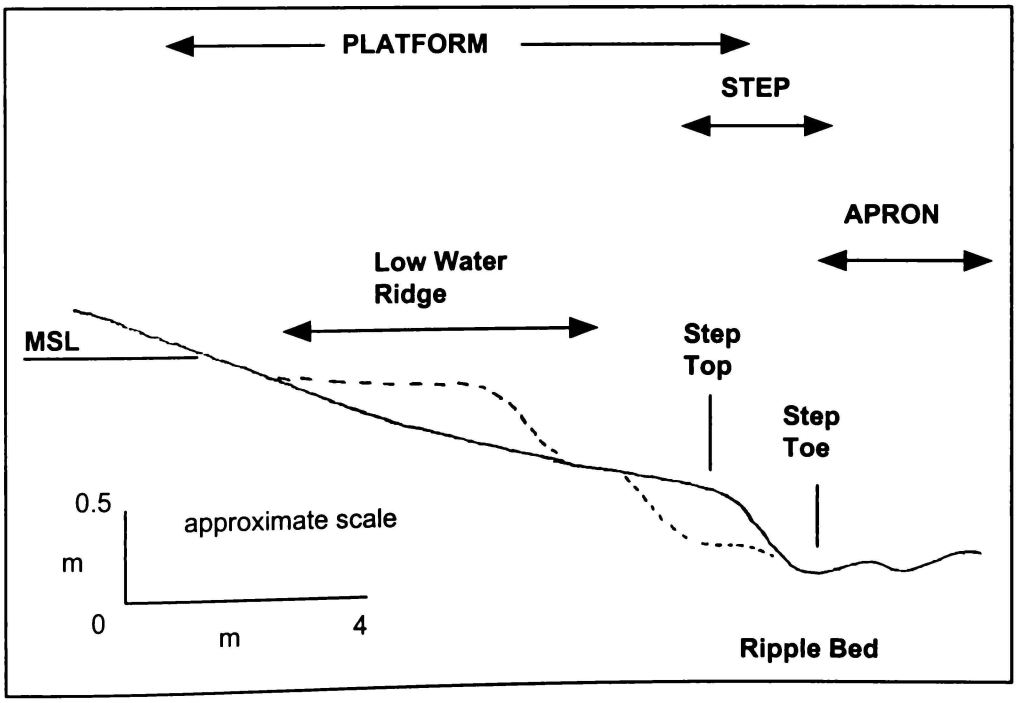
2). Crest, the highest topographic surface above MSL, and

3). Backbeach, is the topographic slope facing landward from the beach crest.

Each of the three segments has distinctive morphological and temporal scales. For example, the beachface can have transitory morphology composed of the swash limit ridges whilst the beach crest and backbeach have longer (storm) interval time-scale morphologies.

The Lower Beachface, (Figure 5.2).

The HB beachface morphology (Figure 5.2), is similar to other MSG beaches reported in the literature. At the base of gravelly beachfaces, a low tide terrace (KIRK, 1980) forms a platform frequently terminated to seaward by a steep slope step (KING, 1959; KIRK, 1980). Along the South Island east



MSL is mean sea level

Figure 5.2. An ideal Hawke Bay lower beachface cross-shore morphology and associated morphodynamic components. The solid line represents a high seas erosional surface, and the dash line represents an accretional surface.

coast to seaward of the step across the inshore is an apron of gentle slope (KIRK, 1980) and HB is similar. In HB, the apron is invariably sandy and it can be rippled and can have shore parallel 'bar' or bars.

The platform morphological bed forms can vary between two broad states namely erosional and depositional.

In the erosional state, in times of high seas, the lower beachface platform can be persistent, or it can erode (hence become transitory) (Figure 5.8). For example, the platform and step are persistent at both Marine Parade and Haumoana even in the highest seas ($H_b = 4.0$ m). Conversely, in similar seas, the platform and step can erode and the platform appears to grade into the apron at Clifton, and Te Awanga. In moderate seas, ($H_b = 2.0$ m) the step can be present at all sample sites. Another characteristic of the lower beachface platforms during high seas are the erosional ripple beds. Ripples can occur at all sites and have an estimated wavelength 0.3 m to 0.6 m; ripple amplitude 0.1 m to 0.03m.

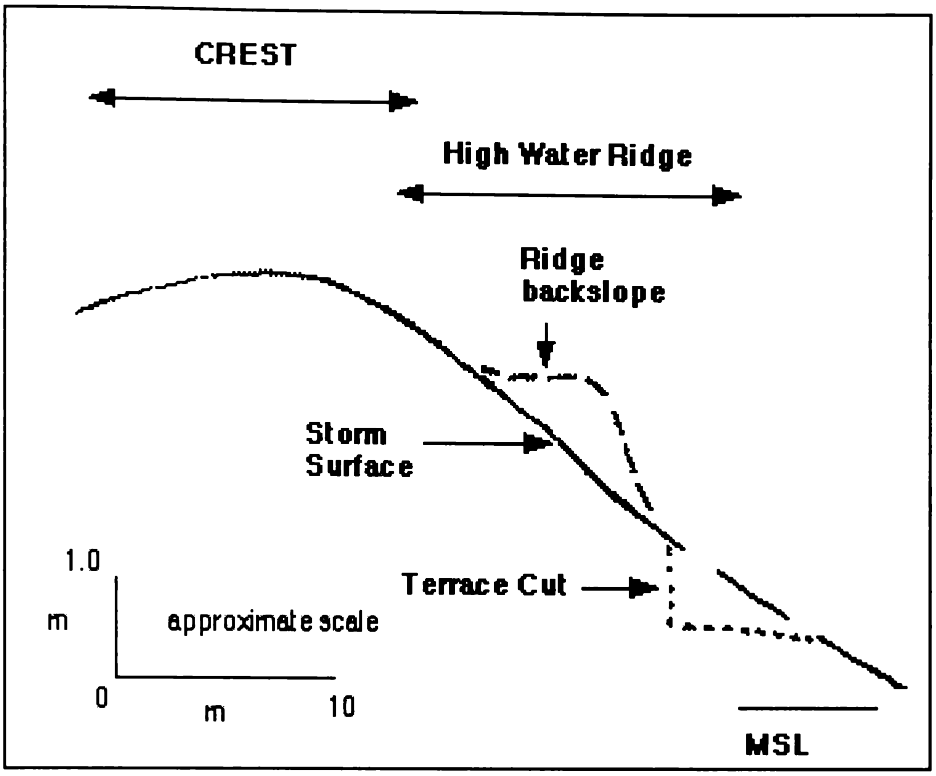
In the depositional state, in times of low wave energy seas, the lower beachface platform can accrete at all sites. In the example (Figure 5.2) the sediment supply is low, hence the sediments erode from the step and deposit on the Low Water ridge (LW ridge). As the sediment supply increases, the deposition takes place at both the LW ridge and at the step. HUGHES and COWELL (1987) have demonstrated similar morphodynamic responses of the platform in Australia. Experiments showed that as the tidal levels increased the platform width decreased, and vise-versa as the tide levels dropped.

Platform sedimentary deposition can form a LW ridge and runnel morphology, but most often the sediments are reworked into low water cusps (LW cusps) that range in thickness (horn tip height) from 0.2 m to a veneer layer one to two clast diameters thick. These LW cusps were targeted for synchronous gravel sampling over a spring-summer season.

The Upper Beachface, (Figure 5.3).

The main morphological form associated with the upper beachface is the HW ridge beach. Similar to the lower beachface the upper beachface morphology can vary between the erosional or depositional state. In times of high seas the upper beachface HW ridge can be persistent, or it can erode. It is possible to relate these morphodynamic changes to the incident wave steepness (B_s) (KING, 1959). Indeed KING (1959) observed that gravely beaches accreted in storms at the upper beachface whereas sand beaches eroded. In times of high seas at the Te Awanga Hall site, on occasion the accretion of gravels as a well-developed HW ridge complete with a backslope (see Figure 5.10) takes place. Often the HW ridge reworks into a cuspate morphology and with continued reworking the sediments arrange as a tier of cusps down the beachface (Figure 5.5), similar to those reported for the New Zealand South Island (NOLAN, et al., 1999).

It is also possible during high seas the HW ridge erodes completely. The erosional morphology and morphodynamics are perhaps more tidal and high wave pulse related in HB. For example, as events (perhaps once per year) the terrace cuts (Figures 5.3 and 5.6) are less frequent than storm (high seas) events. Terrace cuts may indicate low sediment supply conditions.



MSL is mean sea level

Figure 5.3. An idealised Hawke Bay upper beachface (cross-shore).

Crest.

The southern HB transgressive barrier crest is not of uniform height in the alongshore direction. In south-east Ireland a coarse sediment beach crest alternates between topographic highs and low “throats” (CARTER and ORFORD, 1981). Throats can have cross-beach channel flow sediment fabric indicating that the throats are structures and are passages for overwash sedimentation (CARTER and ORFORD, 1981; ORFORD and CARTER, 1982) and HB has a similar morphology.

The storm run-up limit determines the beach crest height configuration in the South Island, New Zealand (KIRK, 1980) and for cobble beaches in California (LORANG, et al., 1999). LORANG et al. (1999) show that the run-up limits are a function of wave steepness and a similar relationship could be applicable to the high seas swash run-up zenith and depositional, and erosional morphological responses in HB.

Beach crest height is thought to be a function of sediment supply and hydrodynamics. Two contrasting ideas are suggested :-

1). Along progradational sections of the New Zealand South Island east coast with an abundant sediment supply the seaward beach crest corresponds to a storm berm and has a greater height (KIRK, 1980). The beach crest morphology can depend on the rate of supply and the sediment supply grain sizes, for example FORBES and TAYLOR (1987) suggest that if the sand content increases the beach crest can develop sand dunes, whereas with less sand the crest is gravely. ORFORD (1986) suggests in a low sediment supply situation, as in west Wales, the upper beach builds up by storms into a high beach crest. In other low sediment supply situations, for example in Boston Harbour, USA, a single asymmetrical overtopping ridge migrates landward during storm events (ROSEN and LEACH 1987).

In the above situations the beach crest height increases.

2). In contrast along sections of the New Zealand South Island east coast as long term erosion continues the beach crest height decreases and leads to increasing overtopping and overwashing (KIRK, 1980) presumably a function of low quantity sediment supply.

In southern HB the crests with longshore undulatory topography are conspicuous along the Mid Holocene multi-crested barrier, between Clifton and Haumoana, and nearer Scinde Island along the contemporary single crest barrier. The contemporary crest has low topographic throats and in high seas sediments can overwash, for example on 4 April 2002 between Clifton and Haumoana.

Backbeach.

The backbeach is landward of the beach crest and slopes landward, except if backed by cliffs in which case the backbeach in the South Island, New Zealand, is planar (KIRK, 1980). There are strong links between the backbeach and beach crest morphology and the sediment grain sizes and supply (CARTER and ORFORD, 1981; FORBES and TAYLOR 1987). In HB the backbeach morphology can comprises four forms, (i) overwash surface, (ii) fans, (iii) lobes and (iv) shutes (scour channels). The overwash surface is a planar surface at Clifton and Marine Parade. These surfaces are overtop deposition upon the contemporary crest that is welding onto an antecedent barrier crest with no backbeach downward slope. Usually in HB the active backbeach slopes have runs of gravel that usually occur as fans or shutes whilst the inactive backbeach slopes have a cover of lichen. Overwash fans have a low angle terminal landward face (CARTER and ORFORD, 1981) whereas the lobes have a steep angle terminal face. Fans are sheet deposition, whereas lobes are a narrow flow deposit. Lobes originate near a throat and extend landwards across the backbeach. Lobes are usually very coarse grained, whereas fans are finer grained. The processes considered to produce these morphologies are overtopping swash with overwash sediment deposition (KIRK, 1980; ROSEN and LEACH, 1987). Sand lobes can also occur because of through barrier water seepage (ROSEN and LEACH, 1987). Seepage can issue from either landward (FORBES and TAYLOR 1987) or seaward (McKAY and TERICH, 1992) of a barrier crest. Seaward seepages have an ephemeral water body immediately landward of the beach ridge. In HB the seepage flow through the barrier usually takes place at ephemeral inlets, for example at cuts through the barrier for drains and at old riverbeds. Seepages may also be taking place as fresh water springs. Seepages are important for sediment transfer between the land and the sea (McKAY and TERICH, 1992) or too landward (FORBES and TAYLOR 1987).

The transitory morphology.

There are two measurable transitory beachface morphologies above MSL, the ridges and the cusps, (as reworked ridges). About MSL is the LW ridge and below MSL is the step. The step is perhaps the most morphological responsive feature on the HB barrier. HUGHES and COWELL (1987) demonstrate the transitory nature of a beach step in response to tidal. In HB, the step is frequently present, under normal wave conditions (H_b > 2.0 m, but depends on high seas duration, for example in a 1 day event the step self maintains, over 3 days the step vanishes). In high seas the beachface can steepen and the step merge with the apron whence the step sediments may disperse across the apron. Figure 5.7 indicates this transitory nature of the Lower beachface at Te Awanga Hall. The Scinde Island, Marine Parade and Haumoana appear to have a permanent physical step. Where the step reforms it becomes a platform with a seaward steep face. On the platform, a LW ridge can have a runnel to landward, especially in summer.

KING (1959) describes two ridge forms, a storm ridge and a high water swash limit ridge. Ridges can build in a storm or at a tidal high water, especially on an increasing spring tide at the swash run-up zenith. Ridges then remain stranded as the storm or spring tide water levels drop. At other times with a steady swash zenith the ridge crest can accrete as overtop deposition takes place (Figure 5.6). If the swash zenith increases then the ridge can be overwashed and deposition takes place landward of the ridge (Chapter 11).

NOLAN, et al. (1999) describe cusps as longshore rhythmic crescentic topography along the South Island east coast. Like ridges, cusps form as a tier at elevations above mean low water springs (MLWS) and these elevations are related to the incident wave breaker height on MSG beaches.

Beachface Planform Longshore Morphology.

Figure 5.4 shows the generalised HB planform beachface morphologies that range from those observed at typical low to a high wave energy event. These beachface morphologies occur over yearly to decadal time scales and generally represent a summer low energy to winter high energy typology.

The HB beachface has a recognisable cuspate morphology and can have distinctive sediment textural sorting patterns similar to those discussed by SHERMAN, et al. (1993). The HB field sites have three forms of cusp, (1) attached, (2) detached, and (3) cross-shore.

1). Attached cusps are attached to the barrier crest, or storm ridge, and have gravelly horns and can have sandy to gritty bays (Figure 5.5).

2). Detached cusps are at the low water position and are detached from the HW cusps and occur as isolated 'islands' of gravels, surrounded by finer sediments that can be sands to grits invariably in the adjacent cusp bays (Figure 5.5).

3). Cross-shore cusps can extend from high to low water (Figure 5.5). These can be asymmetric in planform. Initially in high seas, the cusp horn can point into the incident wave crest approaching obliquely to the shore. Later the horn shifts to pointing directly to seaward, and later still, the horn can shift to a downdrift direction.

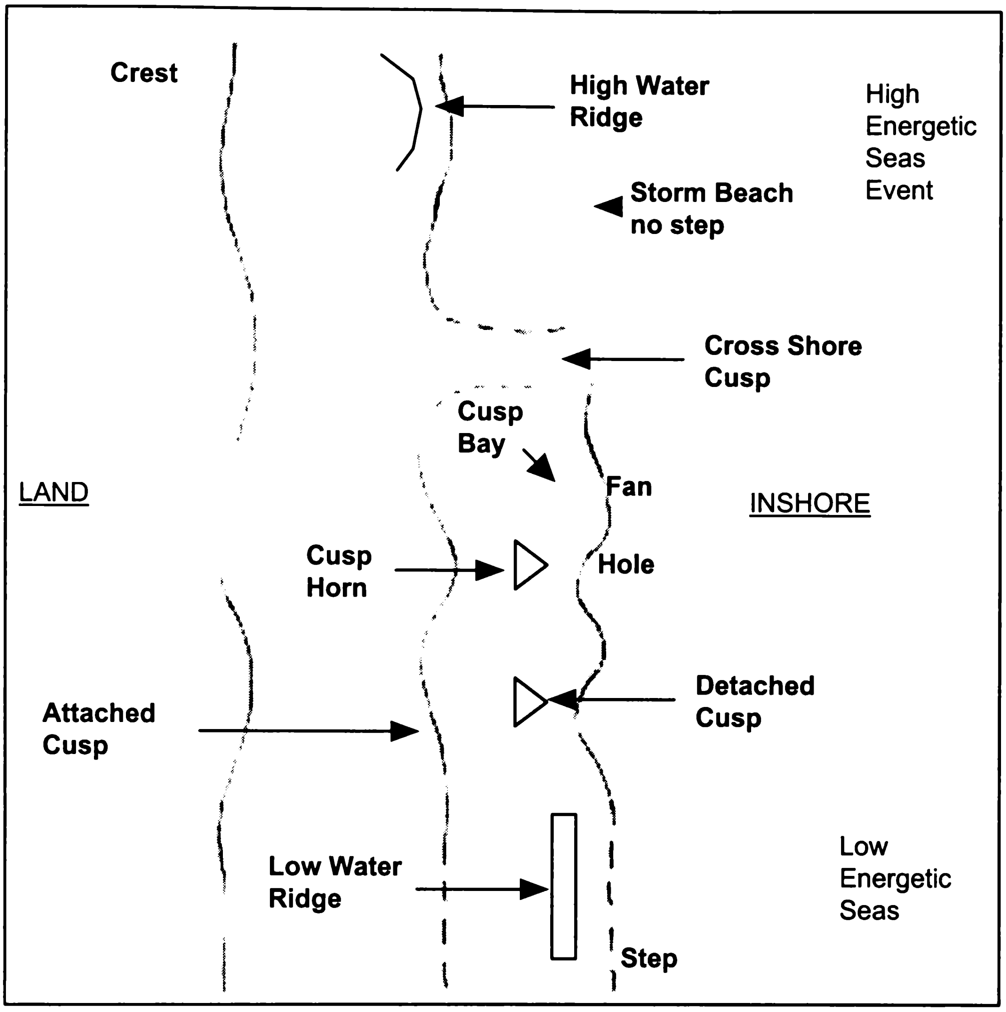


Figure 5.4. Ideal planform beachface morphology ranging from high energy 'winter' plane bed beachface to well developed cuspate and low energy 'summer' low water ridge.

5.3. Morphodynamics and Processes.

The four hydrodynamic processes that characterise steep slope beachfaces are, (1) swash/backwash and (2) by wave reflection (KIRK, 1980; MASON, 1997) off a steep slope beachface. (3) the wave steepness at the break, an empirical dimensionless equation. In HB the breaking wave is invariably well defined at the step, unlike dissipative beaches with a wide breaking surf zone. (4) Percolation of the swash across the coarse sediment beachface is also an important process and reduces the uprush (LOVELESS, et al., 1996).

Exposed MSG beach process dynamics involve incident wave reflection from the steep beachface slope and the distinctive morphosedimentary characteristics (CARTER and ORFORD, 1984). Wave steepness is a useful parameter, see Chapter 6 for the definition. Wave steepness has proved useful for field experiments on the incident wave swash run-up limit on an exposed Californian cobble beach to determine the beach crest height (LORANG, et al., 1999) and the storm beach sedimentation in Wales (ORFORD, 1977).

Thoughts on the processes to the accretion of coarse gravels at the run-up limit differ. LORANGE, et al. (1999) suggest the coarse sediments transport up the beachface by the incident wave swash. This is contrary to SHULMEISTER and KIRK (1997) who suggest that the beach ridge crest accretion is not a process of "enhanced transport of gravels" but is a process of selective sediment fractionation where finer sands winnow and the subsequent concentration of gravels as a lag. KIRK (1980) found "only 20-60 per cent of incident wave energy is translated into run-up and backwash velocities, the proportions declining as wave energy increase" possibly as a result of wave reflection.

(John White print 11)

Figure 5.5. Westshore, Napier, 27 June 2002, low water 0948. The beachface has three cusp morphologies. 1. Cross-shore, 2. Attached and 3. Detached. The cross-shore cusp is to the right and extends from low to high water. The attached cusp is up beach from the surveyor (MARK STUCKEY) at the high water. The detached cusp is down beach from the surveyor in the swash.

A study of a sheltered MSG beach (a swell wave accreting beach) at Kalamata, Greece, with a step profile and low wave steepness, suggests the beachface slope between the beach crest and the step is related to the breaking wave height and the mean sediment size (MOUTZOURIS, 1991). A feature of the sheltered indented Bracken Beach, NSW, described as a MSG reflective beach (WRIGHT, et al., 1979) is the wave energy has a shore normal incident wave approach (wave refraction) about headlands (BRYANT, 1982) and this is similar to HB, where the wave refraction (Chapter 2; GIBB 1962) may be important and in HB a longshore wave energy gradient is apparent from low energy Clifton to high energy Marine Parade.

HB cuspate forms suggest there is a swash zenith and topographic height relationship. A similar relationship was also noted by JENNINGS and SCHULMEISTER (2002) when suggesting a classification for New Zealand South Island MSG beaches based upon the Iribarren number (the ratio of the morphodynamic beachface slope and the incident wave steepness). MASSELINK, et al. (1997) have also established a link between cuspate morphodynamics and the Iribarren number for a sand beach, Perth, Australia. Indeed there is a suggested link between the swash run-up zenith and the surf scaling parameter (GUZA and THORNTON, 1982) (a derivative of the Iribarren number).

The swash characteristics are a likely function of the step stability as noted in Section 5.2. The step morphologic responses relate to the incident wave height. As waves increase in height, off LW cusp horns the step topography becomes a hole, and off the cuspate bay the step becomes a fan (a sedimentary wedge, as a continuation of the cuspate bay surface to seaward). Because of the step configuration and the adjacent LW cuspate morphology there is a longshore series of holes and fans

(Figure 5.4) and these can exert some considerable influence of inshore water circulation. The holes and LW cusp have a steep slope to seaward and the incident wave reflection can take place throughout high seas events, or at least before the step erodes. Such steep slope morphodynamics at the step below mean low water springs (MLWS) suggests the HB beaches are similar to the reflective beaches in New South Wales (NSW), Australia where WRIGHT, et al. (1979) establish a link between the morphodynamics and the surf scaling parameter.

There are generally two main morphodynamic components forming the beachface, (1) the permanent beachface slope, and (2) the transitory ridges, cusps, and the step although these forms can persist. The 'permanent' beachface can be defined as the storm scour limit where for a storm there is a maximum scour limit with little further erosion during the duration of the storm (FUCELLA and DOLAN, 1996). However, with MSG beaches it is not all scouring in a storm since gravel beach crest heights can increase in high seas (KING, 1959) as reported for the South Island east coast gravel beach crest in episodic storms (SHULMEISTER and KIRK, 1997).

5.4 The Morphological and Hydrodynamic Relationships Observed at the Te Awanga Beachface.

The following Sections show some of the observed responses between the beachface morphology and the wave. The wave includes the tide and the gravity and infragravity wave and in the erosional and accretional states. It is considered that the morphological responses become the morphodynamic alterations, including overwash, of a coarse clastic beach and are a primary product of the gravity and infragravity waves (CARTER and ORFORD, 1984). To demonstrate the breaking wave characteristics, morphodynamics, and sedimentation a series of photographs are shown.

The Beachface Morphology and Tides.

Observations and cross-shore transverse profiles indicate that across the Te Awanga Hall beachface there are two main morphological responses to tidal water levels. Firstly, the HW springs can be accretional as sediments accumulate and build HW ridges, as a tier of ridges. Secondly, HW springs can be erosional resulting in a dramatic terrace cut.

High Water Ridge Tiers.

Under certain conditions, tiers of ridges can occur at different topographic heights across the upper beachface. These ridges can form over a time interval involving both the waxing and the waning spring tide and the associated wave activity.

Under 'usual' conditions, the upper beachface morphology comprises a single HW ridge (for example, Figure 1.6, Te Awanga Hall at the cross-shore distances some 34 m, see cross-shore transverse profiles Chapter 7) well above the tidal HW level. This suggests that the morphology of the HW ridge interrelates to the incident wave break and the subsequent swash run-up zenith, and the tidal water level.

On the waxing spring tide the elevation of the swash run-up zenith increases. In these conditions, the sediment deposition can occur further up the upper beachface. As the spring tide wanes the deposits at the HW ridge rework by waves and on each successive lower tide the sediments deposit at the swash zenith but at lower elevations.

(John White print 30)

Figure 5.6 Te Awanga Hall, 19 June 2001, low water at 0945. View south from the Te Awanga Hall cross-section rail. Tier of reworked (cuspate) HW ridges. Wave reworked HW ridge on 17 June 2001, inshore breaking wave (H_b) 2.0 m. Tern hovering to right in line with Te Awanga Reef headland.

All beachface ridges can have a cuspate morphology that could be edge wave related or are perhaps a mechanism related to self-organising as outlined by COCO, et al. (1999). Generally, all ridges across the upper beachface zone are incident wave reflective. It is possible to relate particular sets of cusps (measured by horn spacing and elevation) to Mean Sea Level (MSL) where maximum horn spacing (reworking of a HW ridge) occurs at maximum elevation above MSL (NOLAN, et al., 1999) and high-energy waves. "Subsequent reworking by wave and wind action" produces decreasing horn spacing at lower beach profile elevations (NOLAN, et al., 1999). This suggests that waning high seas especially if coupled with a waning spring tide subsequent reworking of a HW ridge could lead to tiers of ridges down the beach profile towards MSL. For example, Figure 5.6 shows the beachface at Te Awanga Hall on19 June 2001 after a high seas reworking of a HW ridge.

High Water Ridge Terrace Cut.

Over the study, well-developed terrace cuts occurred at Clifton (Figure 14.2), and Te Awanga (Figure 5.7). However, over the same time period, terrace cuts did not occur at Haumoana or Marine Parade. The presence, or absence, of this morphology could be sediment texture related. For example, PONTY (1995) suggests the sand content could have some bearing on the formation of scarps at the Suffolk coast (England).

(John White print 28)

Figure 5.7 Te Awanga Hall, 2 October 2000, low water at 1606. View north. Towards the end of a long flat spring tide 1.6 m to 1.7 m. High water terrace cut and a scarp (height of terrace is 0.72 m (measured 12 October 2000, see Figure 7.8). Swash zone has sands and isolate clasts. Upper swash gravel veneer of down-combed gravels from the antecedent HW ridge and at Low water a gravel veneer on the lower swash platform.

It was observed that there are lead up sequences before terrace cutting. A sequence usually starts with (1) an accretional HW ridge, followed by (2) a long duration neap tide and later (3) a shorter duration spring tide. Over this time the HW ridge supposedly becomes well compacted by natural settlement. Finally, (4) the deposits are exposed to a waxing spring tide with a low incident wave height H_b 0.3 m to 0.5 m that etch and scour the antecedent HW ridge, leaving (5) a terrace cut.

Figure 5.7 shows both the upper swash and platform with a cuspate morphology composed of veneer gravels. These veneers also act as morphological proto-ridges on the platform viz. by trapping smaller sizes so that accretion takes place forming a summer bar as a LW ridge perched on the platform. On subsequent tides with suitable waves, the LW ridge may migrate up the beach to coalesce with the HW ridge. A cross-shore transverse profile shows this terrace cut on 12 October 2000, as part of a gravel sampling routine on 28 September 2000 for the gravel characteristics associated with a high water sapping (erosion) of an antecedent HW ridge (Chapter 10).

The Beachface Morphodynamic and Infragravity Wave Erosion and Very Early Accretion.

To illuminate how the breaking wave characteristics may cause morphodynamic erosion and very early accretion to the HB MSG beach a series of photographs are shown, Figures 5.8 to 5.9. The first photograph (Figure 5.8) shows an erosion beachface (1 December 2002) and the second (Figure 5.9) the very early accretion. The waveforms associated with these events are: -

1). Figure 5.8, 1 December 2002. An inshore wave break seaward of the morphological step. HW ridge sapping (erosion).

2). Figure 5.9, very early depositional 2 December 2002. As a time sequel the wave break is now at the step (the usual wave breaker line), and early accretion (proto-cusp) is at the low tide platform.

(John White print 24)

Figure 5.8 Te Awanga Hall, 1 December 2002, 0900. Low tide at 0912, height 0.1 m. This is an early spring tide (height range 1.7 m to 0.1 m). View northeast showing an inshore 'erosional' wave break as a spilling wave crest. Erosion is the down combing of HW gravels. There is evidence of HW ridge accretion, as the darker grey 'wet' finer gravels landward of the rail irons to the left. These finer gravels partially blanket the coarser lighter grey 'dry' gravels. Photograph from topographic BM (BM for the Te Awanga beachface topographic surveys, 27 July 1998 and 20 April 1999, DAVID ZORN, HBRC have data). See also Figure 5.6 for similar wave breaker types at the step.

Later from 2 December to 4 December 2002, at the HW swash zenith a HW ridge built from the accumulated sediments. This accumulation was measured by the vertical height of sediment at the Te Awanga Hall cross-section rail iron (first rail iron on the left in Figure 3.5) see Swash Topography Sub-section below.

From Figure 5.8 the erosion event morphology and breaking waves: -

1). The usual wave break is about a line connecting the tops of the vertical rail irons spaced along the beach. The rail irons are along the HW ridge being sapped (similar event described in Chapter 10). Within the swash zone is a cross-beach cusp and another off the observers right. At the usual wave breaker line, a standing wave crest break indicates the hydrodynamics of 'erosion' (a relatively long period backwash) and the bathymetry (shallow water platform, step fan).

2). The inshore breaker type is spilling or plunging. The type of inshore wave break depends upon the tidal level and the step morphodynamics. At low tide the wave breaks as a spiller and at high tide as a plunger. In the image, the step is weakly developed with a small topographic elevation. Over the cusp depositional fans the wave break is spilling, but off the cusp horns and over a scouring hole the wave breakers are plunging, which at this stage of the tide often progresses as a bore. Evidently, the inshore wave break is influenced by flow off the beachface projected seaward as a confined current.

This confined current discharges as backwash from the beachface cuspate bays and resembles a rip typical of sandy beachfaces. The effect of a backwash (jet) flow on meeting an incident wave crest is to stall the wave crest especially when the incident waves have wide troughs and narrow width asymmetric wave crests.

(John White print 10)

Figure 5.9 Te Awanga Hall, 2 December 2002, 1100. Low tide at 1013, height 0.1 m. A spring tide. Beachface step wave break, early beach sedimentation (proto-cusp). Proto-cusp is the dark dry spot in the backwash fronting the central wave break about to surge.

Figure 5.9 is a sequel, taken one day after Figure 5.8. Figure 5.9 was taken at a position 30 m seaward of the Te Awanga Hall seawall. The wave breaker types have three wave crest lengths. Accretion can be seen as a 'dry spot' fronting the central stalled wave. In the photograph the wave crest is gaining height to the right, and is starting to surge on the left where the wave base is well advanced up the beachface. On most occasions these wave types do not break and exhibit a jet flow up the beachface. It is these wave types that can propel gravels, via saltation, and can induce 'projectile transport' where clasts are thrown clear of the water so they transport through the air and up the beachface to beyond the flow zenith.

To the left the breaking wave has two crests a foreground stalled plunger with crest collapsing, and just seaward, a second spilling wave with a foaming crest. The wave crests frequently combine and travel up the beachface as a bore. To the right a foaming crest plunging wave is observed with a forward spilling turbulent wave crest.

The breaking wave steepness (B_s) during these observations were: -

Date	Wave Type	Wave Parameters
1 December 2002	inshore wave	$H_b = 2.14$ m; $T_b = 8$ s; $B_s = 0.0584$
	step wave	$H_b = 1.26$ m; $T_b = 6.52$ s; $B_s = 0.0549$
2 December 2002	foaming plunger	$H_b = 2.4$ m; $T_b = 10$ s; $B_s = 0.0495$.

According to the GALVIN (1968) classification Figure 12.1, the wave steepness (B_s) is definitely 'spilling'.

The Swash Dynamics.

From Figure 5.9 the swash has two component flows namely backwash across the beachface and percolation. Firstly, there is a flow asymmetry directed towards the observers left (to the north). It is this backwash that on meeting the incident wave imparts momentum causing the incident wave to stall and gain height before collapsing up the beachface. The second backwash component flow has convergence off the proto-cusp, towards the hole as waters pour off the adjacent fan at the standing surger. This also increases the wave height and the water depth locally. Flow into the beachface (percolation) is at the mid-beachface as a dry spot, in Figure 5.9 as the dark grey patch in the backwash fronting the central standing surger.

Swash Topography.

There are three main geomorphic elements observed on the beachface that have identifiable morphodynamic process. These are (1) the step (at the wave breaker line); (2) the low tide swash platform (saturated zone in Figure 5.9), and (3) the HW ridge.

1). At the step are two sub-aqueous geomorphic forms, termed the fans and the holes (Figure 5.4). These alternate at regularly spaced intervals in the alongshore direction. The fans have greater topographic elevation than the holes (a difference of 0.4 m measured) and are located off the lower beachface bays (and beneath the plungers), whilst the holes are off the proto-cusp horn (beneath the surger). My observations show that the holes have an important relationship with the incident breaking wave. Holes have deeper waters allowing incident waves to break further landward. At the fans, the waters are shallow and this initiates an earlier wave break. Hence, fans and holes have opposite topographic-hydrodynamic process effects. The step hole wave break has some bearing on the relatively rapid accumulation of sediment at the protocusp locality and later as the tidal water levels increase at the swash run up zenith at the HW ridge.

2). On the platform, the topographic elevation increases as the proto-cusp (Figure 5.9) fronting the central standing surger accumulates sediment (initially coarser gravels). Adjacent to the proto-cusp the bays are topographically lower with deeper backwash waters.

3) The HW ridge increased in topographic elevation from the 2 December 2002. At the Te Awanga Hall sampling site the cross-shore transverse profile line has a vertical rail iron at a cross-shore distance of 30 m from the Bench Mark (BM). Measurements from the top of the rail to the sediment surface were recorded over the duration of the early December 2002 high seas event as: -

Date	Height (m)	Process
30 November 2002	1.05	
1 December 2002	1.28	erosion
2 December 2002	1.05	accumulation
3 December 2002	0.97	accumulation
4 December 2002	0.96	accumulation

Clearly, accretion at the HW ridge took place as sediment deposition took place.

Sediments.

In Figure 5.9 two sediment textural sizes are visible, (1) sands in the foreground, and (2) gravels across the swash zone.

1). The sand sizes have two depositional modes. The photograph centre (Figure 5.9) has a soft depositional veneer and to the right and down beach are fill deposits (where the coarse gravel matrix has an open fabric clast-clast contact, allowing fines to fill the void). The soft veneer deposits are derived from either the HW ridge via a process of swash sapping and down combing of fines, or are from the inshore via the step. A proportion of the soft sands could be derived from the step, which are transported up the beachface by turbulent dissipating bores, hence a rapid deposit veneer. The photograph (Figure 5.9) shows a brown-yellow colouration in the standing wave breakers. This is a sand population that could be composed of sands derived from both the step-apron and from the backwash. These soft sands also have a sharp junction with the beach gravels where swash has removed the veneer sand exposing the very well sorted gravel sizes beneath, these are a lag deposit.

2) Firstly, above the saturation (Figure 5.9) are longshore bands of coarse gravels outcropping as discontinuous antecedent deposits, or fixed lag sheets. The swash scours the beachface exposing these antecedent sheets that often contain incongruous sizes to those transporting in the swash, in this example, the antecedent gravels are larger than the saltating very well sorted fill population. Secondly, depositional modes composed of 'mobile sheets'. There are two sorted sizes, populations (A) and (B). At the platform are the coarse sizes of population (A). Towards the swash zenith are the finer sizes, population (B) that saltate rapidly in the expending energetic wave bore. Hence, a process of gravel selection by sorting via over-passing. The platform coarse gravels sort via a process where the large clasts are rejected and transport over finer grain sized beds (ISLA, 1993). CARTER and ORFORD (1991) also suggest rejection gravels can be rejected both down the beachface, but also up the beachface and may become overwash deposits. Hence, coarse gravels can transport down the beachface, or remain as a lag deposit whilst finer gravels transport up the beachface.

The Beachface Morphodynamics and Infragravity Waves and Deposition at the High Water Ridge.

Early August 1999. The photographic sequence (Figures 5.10 to 5.11) is an example of high-energy wave breaking at the step and accumulation at the HW ridge. This sequence corresponds to time intervals 12 to 13 on the transverse profile time series Chapter 7 and Appendix 11, Te Awanga Hall. (In Appendix 11 comparison between profile sites and the beach response to a high seas event is possible because the sample sites are synchronous).

Wave Breaker Types.

Figure 5.10 shows the breaking wave types at low water. Note the wave breakers and topography are the reverse to those in Figure 5.11. The wave breakers are now a 'spilling' type (called here a foaming plunger) breaker over the step fan off the cusp bay and off the cusp horn a plunging breaker over the step hole.

Figure 5.10 shows the inshore high tide wave crest type. This wave has a well-developed asymmetric crest and is gaining height to the right, a darker wave face, and is possibly doing so in response to inshore shallowing bathymetry.

The accretional HW ridge wave breaker type (B_s) over the high seas event are: -

Date	Wave Type	Breaking Wave Parameters
4 August 1999	foaming plungers	$H_b = 2.0$ m; $T_b = 10$ s; $B_s = 0.045$
5 August 1999	foaming plungers	$H_b = 1.5$ m; $T_b = 11$ s; $B_s = 0.035$.

(John White, print 4)

Figure 5.10 Te Awanga Hall, 5 August 1999, 1200. High tide 1129, height 1.6 m. End of neap tide cycle range 1.5 m to 0.2 m. High seas high water ridge accretion, from saltating medium sizes (8 mm to 12 mm; -3. 0 Phi to -4.0 Phi) depositing as overwash and overtop sedimentation. The HW ridge has good water percolation (gravels are clast-clast contact with open voids) and the combined percolation and ridge topography induces a reflective beach (in Appendix11the beachface does become relatively more reflective with a change from dissipative to linear).

Swash.

Two types of swash flow are apparent with firstly, flow across the swash (Figure 5.11) and percolation into the beach, Figure 5.10. Figure 5.10 shows the swash run-up actively percolating into a HW ridge. The open fabric (clast-clast contact) allows maximum percolation and the retention of water hence reducing the backwash flow. As the HW ridge accumulates the backwash flow reduces further as the void volume increases. The wave run-up waters can also overtop a HW ridge and temporarily pond at the base of the HW ridge backslope before slow percolation. Percolation therefore reduces the return flow and effectively increases the beachface reflection.

Swash Topography.

There is an evident accretional HW ridge (Figures 5.10 and 5.11) with a cuspate morphology and a very well developed HW ridge backslope (Figure 5.11).

(John White print 2)

Figure 5.11 Te Awanga Hall, 5 August 1999, 1200. High tide 1129 height 1.6 m. End of a neap tide cycle range 1.5 m to 0.2 m. Note the high water ridge sedimentation with a cobble sized deposit, overlain by finer gravels at the crest in the left foreground. These cobble sizes assist the saltating and projectile transport of finer gravels towards the beach crest, where the smaller sizes bounce off the larger sizes. Note also the HW ridge topographic height compared to the adjacent beachface, and the beach crest. The new HW ridge has a well-developed cuspate planform.

Sediments.

The gravels are distinctively zoned in Figure 5.11 with the finer sizes at the HW ridge crest and the coarser sizes across the upper beachface. The HW ridge crest has very well sorted medium sized gravels, and isolate large gravels and is an example of a saltating mobile sheet deposit (Figure 5.10). Across the upper beachface the gravel sizes are small cobbles sizes with a fill of large size gravels passing into medium gravels towards the HW ridge (Figure 5.11). The isolate large gravel sizes are an example of gravel deposition by saltating, overpassing, and deposition at the HW ridge. The cobbles are a traction deposit.

5.5 Discussion.

Wave effects on the beachface morphology in southern HB can be shown to be either accretional or erosional. High-energy seas can accrete a HW ridge and as the tidal level wanes so sequential, ridges deposit forming a tier of ridges down the beachface. Conversely, an erosional tidal effect can take place on waxing springs with a small wave. As the tidal water level elevates the small waves can erode an antecedent HW ridge producing an erosional terrace cut. These terrace cuts prove a most useful exposure of the internal sedimentary structure of the HW ridges. It should be noted that the terrace cut morphology was only observed between Te Awanga and Clifton. This selective morphological development could be a function of the sand content (PONTEE, 1995) but may also be a function of compaction.

Further, the tidal height variation along the southern HB coast could be similar to that reported for Seaforth Beach, Queensland by SHORT (1991). This similarity suggests a greater tidal variation could occur towards and at Cape Kidnappers where over the submarine platform the tidal waters could become elevated and this may explain the more frequent overtopping and overwashing between Haumoana and

Clifton (compared to Marine Parade). Tidal water level elevation and local bathymetric effects could also explain the terrace cut morphologies observed at Te Awanga Hall, and Clifton where the nearshore is wide and shallow, whereas at Marine Parade or Haumoana the inshore waters are deeper and terrace cut morphologies were not observed.

With waves there are generally two wave breaker zones, depending upon the incident wave height. Two breaker zones are generally seen in times of high-energy seas when the beaches can be in an 'erosional' state. For example, at Te Awanga Hall the wave breakers simultaneously take place at both the inshore and at the step. Low energy waves invariably have a single breaker zone at a well-developed step.

The high-energy inshore incident wave break occurs as a crest spilling wave type as the wave reaches the shallow bathymetry. This shallow bathymetry could in some part be due to the sediments 'eroded' from the adjacent beachface forming inshore bars, or large ripples.

High-energy erosion takes place by a process of swash run-up and sapping of the beachface sediments with the backwash transporting the sediment as overpass to seaward. During these periods, the erosion takes place especially at the HW ridge, also the beachface platform bed decreases in height. In an erosional state, the platform step is one of alternating fans and holes. Fans are topographic elevations likely composed of sediments eroded from the beachface. Holes are scours induced by combined breaking wave turbulence and water pouring laterally off the fans. Wave types associated with the step morphodynamics are: -

The wave breaker types	Holes	Fans
Under erosional conditions	plunging	spilling
During early depositional conditions	surging	foaming plunger
In HW ridge deposition	plunging/surging	foaming plunger.

These breaking wave type variations could be a function of the sediment controls on the step morphodynamics however, this is difficult to determine directly. More obvious and easily measured morphodynamics occur at the HW ridge. Sediments at the HW ridge change from an erosional coarse gravel lag to a deposition mix of larger sizes and often a fill of finer gravel. It is likely that during erosion the coarse HW gravels transport to the step where they 'maintain' a step morphology.

As the wave energy decreases so the beachface accretion begins to take place starting at the step and platfom. Usually in low energy conditions (when $H_b < 1.0$ m) the step morphology is continuous alongshore but in times of high energy seas the step can erode or be weakly developed at all sites except Marine Parade where a well developed step appeared to be always present.

The wave breakers generally have the greater wave height at low tide, however this could change when large quantities of sediment erode from the beach and pass into storage inshore. Such a process would effectively shallow the bathymetry, and this would become even more likely following a river discharge event depositing sediments inshore.

In high wave energy events the combined wave break types may be synonymous to the morphodynamics of sand beaches and the formation of an inshore bar, over which the incident wave can break and reform over a runnel before breaking at the beachface. With sand beaches, the inshore bar moves towards the beachface (KING, 1952) so the HB accretion at the step may represent a similar situation with a shoreward migrating bar as the hydrodynamic wave energy decreases. The step wave break is often accompanied by accretion in the early phase by the increase of topography at the platform and simultaneous, or shortly later HW ridge accretion.

5.6 Conclusions.

1) The southern Hawke Bay beaches have a morphology characterised by a beachface, crest and backbeach. The beachface has transitory lower and upper beachface morphologies. The lower beachface has a sub-aqueous step seaward of a platform upon which a LW ridge may accrete. The upper beachface invariably has a HW ridge. The beachface crest is not of constant height alongshore but has topographic highs and lows. The backbeach in Hawke Bay can have overwash deposits. In high seas, characterised by inshore wave breaking, the transitory morphology changes. The HW ridges can be sapped and the eroded material pass seaward in the backwash. Simultaneously the step height decreases and the platform merge with the inshore apron. Accretional events have the wave breaking at the step, and accumulation can occur rapidly as proto-cusps on the platform. As the seas continue the gravel accumulate at the HW ridge.

2). The wave break usually takes place at a well-defined morphodynamic step.

3). The southern Hawke Bay beaches develop distinctive HW ridge morphodynamic responses to waves and tides. The two end member response is either a tier of HW ridges or a terrace cut. A tier of HW ridges can form after a waxing spring tide and accompanying waves have deposited material at the HW ridge run-up zenith. On the waning spring tide, the waves rework the HW ridge and subsequent ridges sequentially deposit at lower elevations down the beachface. These tiers occur between Clifton and Marine Parade. A terrace cut forms on a waxing spring tide with low amplitude waves. As the spring tide height increases the accompanying waves 'erode' the HW ridge at the run-up zenith in successive 'bites'. The beachface material 'erodes' by block falls and transports towards the lower beachface by a process of down combing in the backwash. Terrace cuts occur only between Clifton and Te Awanga as distinct morphologies. At Haumoana and Marine Parade the distinction is less marked and may be a break of slope.

4). Two main wave breaker forms are associated with 'erosional' and accretional, beachface morphology. At the onset of an erosional phase, the wave breaks as a crest spiller or plunger to seaward of the beachface step. The wave break appears to be tide dependent with spillers more associated with low tide and plungers with high tide. The lower beachface step erodes and can blend into the inshore apron at Clifton and Te Awanga, or can be persistent at Haumoana and Marine Parade. Water circulation on the beachface changes the backwash so that early deposition starts as fans where the backwash circulation returns to seaward. In the alongshore direction at the platform an alternating series of holes and fans develop in waning high seas. Holes occur off depositional proto-cusps and are deep water. Fans occur off cusp bays and produce shallow waters. The different water depths produce characteristic and different wave breakers. Note also that the backwash flows to the holes and can locally elevate the local water depths allowing the wave to break further landward, and subsequently increase the time interval the backwash flows to seaward.

The elevated water levels at the holes produce surger wave break that can project gravels further up the beachface. Backwash concentrates in the bays and the return flow to seaward forms a jet like flow that retards the incident wave crests so that the wave crest break 'stalls' and then breaks as a plunger or a foaming plunger. A foaming plunger has the top 2/3 of the wave projecting forwards, as against the wave crest over tipping downwards in a 'pure' plunger.

As the wave energy decreases further the waves break as collapsing or surging waves over the holes that project gravels through the air to landward and beyond the swash run-up zenith. The gravels accumulating at the HW zone allow run-up waters to percolate into the clast-clast contact gravels. This retards the backwash and allows waves to surge and collapse further up the beachface and increase the net accretion towards the HW ridge.

5). The GALVIN (1968) classification of breaking wave types, surging (collapsing), plunging and spilling does not 'realise' the HB breaking wave types. For example, HB has plungers at high wave steepness ($B_s > 0.04$) and foaming plungers can be accretional, surgers often are accretional and associated with high value B_s (0.035 to 0.045) whereas in the GALVIN classification these wave types are spillers.

CHAPTER 6 THE MORPHODYNAMIC PARAMETERS APPLIED TO THE HAWKE BAY BEACHFACE.

6.1 Introduction.

This chapter reviews the literature on firstly, the breaking wave morphodynamic empirical equations for the coarse gravel beaches and utilised in this study. Secondly, defining the profile changes at temporal scales, for example the storm event characteristics and the 'seasonal' beach profile, and thirdly, the quantitative measure of the profile changes with respect to the sediment volume and the 'profile index'.

6.2 The Breaking Wave Morphodynamic Parameters – Previous Studies.

The morphodynamic parameters used in this study are the surf scaling parameter ε, and the Iribarren number ξ, and the hydrodynamic, linear breaking wave steepness B_s. There is an empirical inter-relationship between the beachface geomorphology expressed as a beachface slope and the prevailing hydrodynamics typified by the shore-normal breaking wave steepness (BATTJES, 1974).

A characteristic of reflective beachfaces is a tiered array of cusps (WRIGHT, et al., 1979). Cusps in New South Wales have an association with steep linear beachfaces and surging breakers, high run-up and minimum wave set up (WRIGHT, et al., 1979). SHORT (1979) proposed a three dimensional beach stage morphology model typified by beachface fluctuations between two end member states, where these are: -

1). Dissipative and concave up, that represents a maximum wave power, storm, winter situation. These beaches also have a minimum sediment volume above a given datum (SHERMAN, 1991).

2). Reflective and convex up, that represents a minimum wave power, calm weather, summer situation. These beaches have a maximum sediment volume (SHERMAN, 1991).

SHORT (1979) suggested that as the wave power decreases a sediment wedge transports onto the subaerial beachface. With a further decreasing wave power, the sediments form cusps at the high tide where the wave reflection is greatest. These morphodynamics can be related to the surf scaling parameter ε. SHORT (1979) also suggests that for coarse sand and gravel beaches (MSG beaches) the surf scaling parameter indicates a reflective beachface when $\varepsilon < 2.5$ and the incident wave swash and backwash with shore normal flow dominates with inshore high mode edge wave. Defined by the surf scaling parameter these reflective beaches are locked into a confined morphological variation dominated by the beach stages 1-2-2' (SHORT, 1979) that is equivalent to the SONU (1973) type C' beachface profile stage. Both stages (SONU, 1973 and SHORT, 1979) have a beachface morphology that is cuspate, reflective, with high tide ridges and a step at the lower beachface.

The surf scaling parameter is related to the Iribarren number, (or surf similarity = ξ) (BATTJES, 1974) (surf scaling parameter $\varepsilon = \pi\sqrt{\xi}$ MASON, 1997) and is given by: -

surf scaling parameter

$$\varepsilon = H_b \omega^2 / g \tan^2 \beta \qquad (1)$$

where

H_b is breaking wave height (m)

ω is wave period as radian frequency $= {}^{2\pi}\!/_{T}$

T is wave period (s)

g is acceleration due to gravity (m/s^2)

β is the beachface slope

GUZA and THORNTON (1982) suggest the link between the surf scaling parameter and the Iribarren number is: -

$$\varepsilon = {}^{\pi}\!/_{\xi^2}$$

where

ε is the surf scaling factor

ξ is the Iribarren (surf similarity) number

The Iribarren number, ξ, has proven useful for steep beachface morphodynamic research. For example, to describe the cusp morphodynamics over time that included a storm event with erosion and subsequent deposition on a microtidal, steep gradient, low energy sand beachface at Perth, Western Australia, MASSELINK et al. (1997) and the relationship with storm beach sedimentation and morphodynamic change at gravely beachfaces in southern Ireland (ORFORD, 1977) and California (LORANG et al., 1999).

The Iribarren number (surf similarity) can include GALVIN's (1968) shallow water wave breaking type (BATTJES, 1974) where the shallow water breaking wave steepness, B_s, can describe the storm upper beachface morphodynamics (ORFORD, 1977). From equation (2) BATTJES (1974) derives equation (4) for the breaking wave steepness used in this study.

$$\xi = {}^{\tan\beta}\!\Big/_{\sqrt{{}^{H_o}\!/_{L_o}}} \qquad (2)$$

where

β is beachface slope

H_o is incident deep water wave height (m)

L_o is deep water wave length (m)

${}^{H_o}\!/_{L_o}$ is the incident deep water wave steepness

Iribarren number, or, the surf similarity number

$$\xi = \frac{1}{\sqrt{2\pi}} \frac{\tan\beta}{\sqrt{H_b / gT^2}} \tag{3}$$

where

H_b is breaking wave height (m)

g is acceleration due to gravity (m/s^2)

T is the breaking wave period (s)

$$B_s = \sqrt{H_b / gT^2} \tag{4}$$

where

B_s is shallow water wave steepness

H_b is breaking wave height (m)

g is acceleration due to gravity (m/s^2)

T is the breaking wave period (s)

The GALVIN (1968) breaking wave steepness can describe the breaking wave type that can range from surging, to collapsing, to plunging, to spilling as the wave steepness value increases (ORFORD, 1977). In an Iribarren relationship, HUNTLEY and BOWEN (1975) suggest surging wave breaks are associated with steep beachfaces (slope β = 0.01) whilst ORFORD (1977) suggests collapsing wave types. In HB both wave types frequently occur and in high seas off the horns of LW cusps during accretion. ORFORD (1977) suggests the storm wave break at a MSG beachface need not be plunging (usually associated with steep beachfaces) but can be spilling. Over a rising tide the storm breaking wave type changes from plunging to spilling and this could account for the storm beach sedimentation towards the upper beachface HW ridge (ORFORD, 1977). In HB during a high seas event as the tide advances the wave breaks over a more gentle sloping cusp bay fan enabling the breaking wave to remain a spilling type (foaming plunger) that may induce up beachface sedimentation.

What is apparent is that there could be a wave type change and a corresponding change of the HW ridge morphodynamics. HW ridge deposition is associated with spilling waves and changes into a reworked HW ridge cuspate morphology with plunging wave types. Based upon GALVIN (1968) definitions cusp presence is associated with plunging breakers. For example a well-developed cuspate geomorphology on the east coast South Island MSG beaches (JENNINGS and SCHULMEISTER, 2002) and a sub-aqueous step beach reflective profile.

6.3 Profiles. Defining the MSG Beach Cross-shore Transverse Profile.

Early studies demonstrated that as a storm continues the beach profile changes and the characteristic changes for a coarse grain beachface were different from those of a sand beachface, where the two noticeable differences for a coarse beachface are the crest builds vertically, and the beachface becomes convex up (KING, 1959; KIRK, 1980).

For the east coast South Island MSG beaches most changes of beach profile take place on the foreshore between the beach crest and the beach step with the largest variations of beachface profile occurring over a storm and post storm interval (KIRK, 1980). The "largest morphological changes occur" across the beachface between the swash run-up limit (or infrequent overtopping) and the lower beachface step, with most morphological change taking place across the "lower part of this zone" (KIRK, 1980). KIRK (1980) found that most of the change takes place with widening sweep zone towards the breaker line.

Changes of the morphology correspond to sediment transport as sediment quantities shift spatially and temporally. Gravely beaches have small sediment quantity shifts. For example, SHERMAN (1991) notes that at the gravel beach near Malin Head, Northern Ireland, the profile variability is low and only small volumes of material move except in storms. KIRK (1980) also notes that temporary accretion along lengths of coast relates to temporary increases of beach elevation. KIRK (1980) suggests that New Zealand MSG beaches are confined as there is no periodic onshore-offshore recirculation of sediments between the beachface and the inshore seabed "as for example, in storm/post-storm or seasonal cycles" so characteristic of sand and some pure gravel beaches.

Sediment quantity shifting can vary over time so that the sediment shift and the sediment supply rate interrelates, for example FORBES and TAYLOR (1987) suggest the beach morphology and rate of sediment supply is important for the overwash sediment facies. Overwash can decrease, locally, the beach crest height and increase the beach width, with no change of sediment volume in the cross-shore profile. ORFORD (1977) suggested that major storm beach sedimentation can build a beach crest that "may dominate the upper beach for months, if not years" especially on beaches where the gravel supply is limited to reworking the existing barrier. Longshore gradients of run-up (from wave refraction variation between exposed to sheltered lee beaches) can lead to variable longshore beach ridge heights.

Morphological change is invariably perceived as a change in beachface slope geometry and this to can have a temporal expression. Over a period of ten years South Island east coast beaches with prolonged erosion, shown by shore retreat, have a trend of beach crest height reduction and marked beachface steepening (KIRK, 1980). However, the beachface slope also depends on the exposure of the beach to the prevailing hydrodynamics and whether the beach is eroding or accreting.

Seasonal changes of MSG beachface geometry are also thought to take place. MASON (1997) suggests the seasonal MSG beachface profile changes compare to sandy beaches, with a summer berm (ridge) that can be missing. PONTEE (1995) found that MSG beachface profiles have greater winter variability over a tidal cycle, with a landward translation of the step on a flood tide and reverse on ebb (KING, 1959; HUGHES and COWELL, 1987). Seasonal changes may depend on the exposure of the shore to wave energy. OWENS (1977) found that sheltered and exposed shores have seasonal profiles. The high energy beach had better definition of seasonal beachface profile change. The low energy beach profile had a more variable wave energy and the beachface 'cycles' had signatures related to storm and post storm accretion. However, this was for sand beaches in the Gulf of St. Lawrence.

MSG beachface profile relationship with winter and storms is similar to that of pure gravel beaches (PONTEE, 1995) but the relationship between storm magnitude and profile is not straight forward (ORFORD and CARTER, 1982; 1985). Storm duration is important (FUCELLA and DOLAN, 1996). The profile response to a storm depends on the sand content and beachface scarps can result when sediments are well compacted (PONTEE, 1995).

In profile, MSG beachfaces are usually narrow and have a steep, convex up beachface (KIRK, 1980), which makes them reflective. There is a dynamic relationship to geometry change as MSG beaches are reflective. MASON (1997), using the surf scaling parameter, found that reflection increases proportionally when the beachface slope is greater than 0.06. Surf scaling parameter equates to a ratio relationship of the incident wave frequency and the reflected wave frequency. For prediction of reflection the incident wave height, wave steepness and frequency are important. Reflection increases with surf scaling parameter until a maximum coefficient of 0.6, the reflection then remains constant despite increasing surf scaling parameter but this incident wave height and reflectivity relationship is not linear (MASON 1997). Reflection increases with beach slope and is almost linear once the beach gradient exceeds 0.08. Swell waves are the most effected but it is not certain if this is slope or beach material related (High Water coarse sediment friction). Reflection of swell waves increases with decreasing wave steepness (breaking wave height, H_b = 0.08 m and wave steepness from 0.003 to 0.006). On the steepest part of the beach (MSG) at Morfa Dyffryn, Wales, the reflection can attain up to 90% of the swell wave energy and the reflection is preferential according to the wave frequency. MASON (1997) found 15% to 40% of wind wave energy reflects irrespective of beach gradient or sediment texture.

KIRK (1980) suggests a wave steepness 0.03 in laboratory tests, and in the field, 0.005 to 0.01 differentiates between erosive (destructional waves) and accretion (constructional waves), where low value steepness is accretional and high wave steepness is erosional. SHERMAN (1991) concurs with KIRK (1980) suggesting that steep storm waves (steepness > 0.01) erode a gravel beach and swell waves (steepness < 0.007) rebuild a beach, but, these steepness are cyclic as they reflect summer swell and winter storms. KING (1959) reports erosion of Chesil Beach in 1949 related to a wave steepness of 0.019.

The beachface slope and incident wave steepness relationships for Australian beaches (SHORT, 1979; WRIGHT, et al., 1979) are: -

1). Winter (storm), erosional, minimum sediment volume, dissipative (concave up) profile and large surf scaling parameter (ε), and small surf similarity (Iribarren number) ξ.

2). Summer, depositional, maximum sediment volume, reflective (convex up) profile, has a small surf scaling parameter (ε), and a large surf similarity, ξ.

Profile studies on MSG beaches have also attempted to place sequences of profile shapes into stages between two end members, with maximum sediment volume and with minimum sediment volume. At two field sites, CALDWELL and WILLIAMS (1985) evolved twelve stages based upon either a linear or a concave up profile and with or without berms (ridges) usually at tidal extremities. Of the two Welsh field sites, representing a low (Gileston) and a high (Nash) energy beach, the Gileston beach displayed “stable phases” for a generalised winter and summer season. Gileston attained a summer accretional profile and a swash berm (ridge) that was not “apparent during winter” (CALDWELL and WILLIAMS, 1986). At Nash Beach, the profile changed constantly throughout the year and ridges were short-term features found at a variety of cross-shore positions (CALDWELL and WILLIAMS, 1986).

ORFORD (1986) designated eight beach profile stages as versions of SONU and VAN BEEK (1971, cited in ORFORD, 1986) profile typology. These profile stages between the concave up and the linear beach profile, as the convex up profile shape is rare at ORFORD's (1986) Llanrhystyd Beach field site. Berms (ridges) define the tidal swash limit, hence ORFORD (1986) also divides the profile about a horizontal to separate the spring and the neap tidal influence on the resulting profile shape. ORFORD (1986) suggests that the berm (ridge) location across the beachface profile is process related, where (1) the High water ridge is fair weather, (2). The Low water ridge is storm related, and (3). The composite ridges are severe storm morphologies.

As ORFORD (1986) notes the SONU (SONU and VAN BEEK, 1971) methods do not indicate the position of the berm (ridge), for example a HW ridge may migrate landward as a short duration storm wave set rapidly builds and decays. It may be possible to apply geometric-dynamic change procedures to these situations, for example VAN DER MEER and PILARCZYK (1986) and SUNAMARA (1989) who investigate the beach profile changes where the beachface has a sub-aqueous step.

6.4. The Quantitative Subaerial Beachface Analysis.

The method used in this study to quantify beach profile change follows that for sand beaches by SONU and JAMES (1973) and FUCELLA and DOLAN (1996) and for gravely beaches by ORFORD (1986). Figure 6.1 introduces the quantitative method used to classify the geometric cross-shore transverse profile for the HB field sites.

This scheme applies the geometric right angle triangle where the area is defined by the equation:

$$\text{Area} = \frac{1}{2}(\text{width x height}) \qquad (5)$$

The triangle area becomes a volumetric measure by assuming the transverse profile is a strip 1.0 m wide. FUCELLA and DOLAN (1996) classify the profile by beach height (h), width (S), volume (Q) and introduce a profile shape index (PI-profile index) based upon the linear profile, where: -

A). Linear	PI=0.5	Q/S.h=0.5.	
B). Concave up	PI=0.35	Q/S.h=0.35	(dissipative profile).
C). Convex up	PI=0.72	Q/S.h=0.72	(reflective profile).

These profile index apply to a sand barrier, Nags Head research station, North Carolina. Further, FUCELLA and DOLAN (1996) relate the PI to wave steepness and storm induced beach volume changes. ORFORD (1986) demonstrated that for Llanrhystyd Beach, south Wales, only two of the three basic profile types were represented, the concave up and the linear profiles where these are defined as: -

A). Linear profile	Q/S.h=0.5.
B). Concave up	Q/S.h=0.45.
C). Convex up	Q/S.h=0.67.

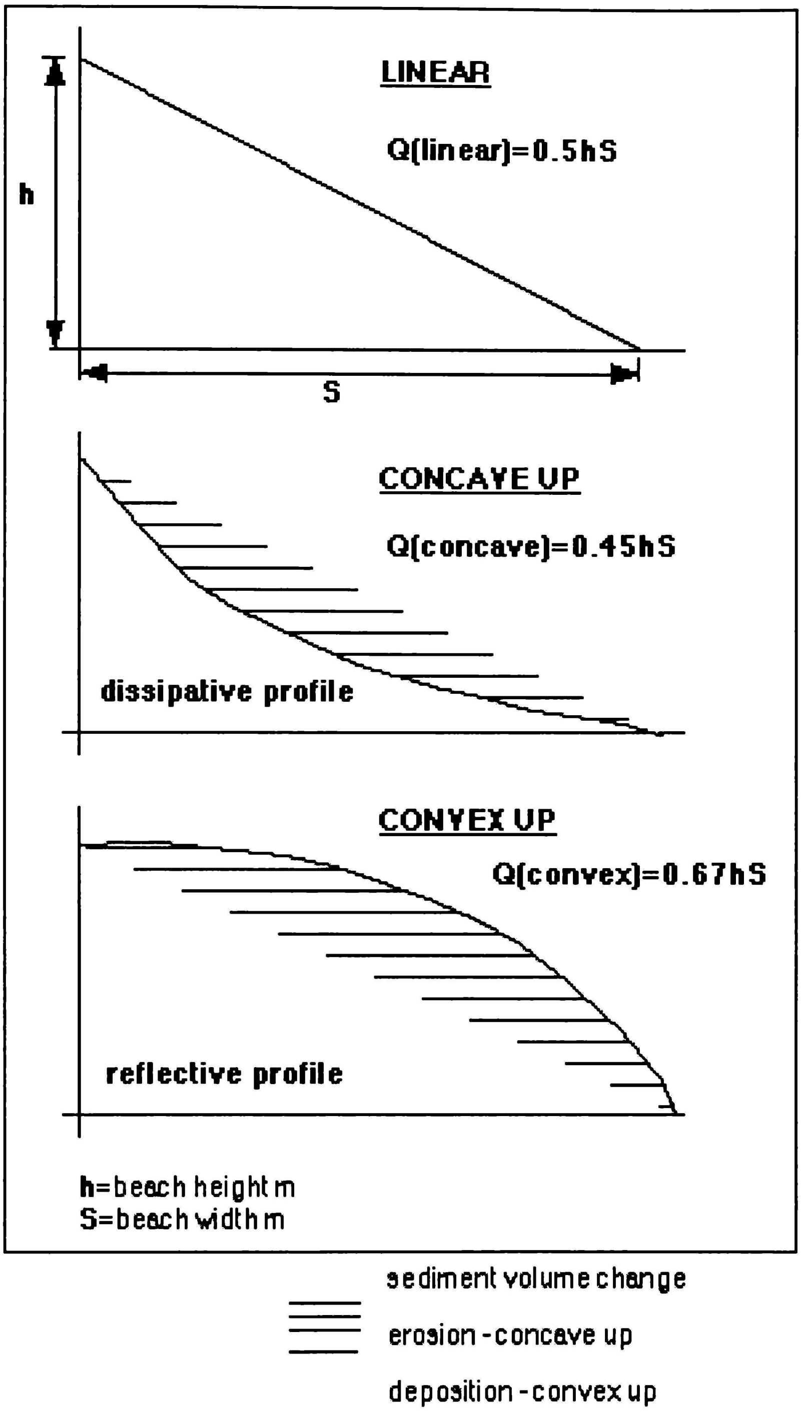


Figure 6.1 Model for beachface cross-shore transverse profile type classification. Profile shape delineators after ORFORD (1986).

Modelling of the beachface morphodynamics could be expressed using more complex methods, for example by sub-dividing the beachface into cross-shore length segments, where the MSG beaches can have ridges, or not. However, different MSG beaches can have different ridge configurations, for example Llanrhystyd Beach has eight ridge configurations (ORFORD, 1986) whereas CALDWELL and WILLIAMS (1985) arrive at ten archetype profiles, although two profile shapes were combined because they are rare. ORFORD (1986) has beach berms (ridges) at two beach profile positions. These positions are either at the lower beachface, or at the upper beachface, or, at both the upper and lower beachface simultaneously. CALDWELL and WILLIAMS (1985) have a similar configuration, but include a possible cross-shore ridge at the mid beachface position.

MASON and HANSON (1989) use cluster analysis to define profile shape classifications for profiles from the Holderness coast, East Yorkshire, a sand shingle beachface up to 250 m in width, backed by glacial till cliffs ranging 5 m to 20 m in height. The beachface slopes vary from south to north along some 3 km of coastline where the slope differences are sediment texture related into (i) an upper beachface that is coarser and (ii) a lower beachface with finer facies. MASON and HANSON (1989) do relate their findings to the incident wave height and found that waves less than 0.3 m to 0.5 m tend not to change the beachface shape, although the upper beach (ridge) may erode. Waves at "around 0.5 m" could rebuild the upper beachface especially if these waves are a pulse of energy. With waves greater than 1.0 m the profiles change was "more extreme" with transfer of sediment from the upper to the lower beachface, however for waves between 0.5 m and 1.0 m the sediment transfer could be either up beach or down beach.

MASON and HANSON (1989) class the defining variables as a measure of the upper beachface shape (concavity/convexity); a similar measure for the lower beachface; the ratio of the upper and the lower beachface (concavity/convexity); the upper beachface slope, and the lower beachface slope. These parameters become part of the formulation for a single chain Markov model that relates the parameters to the incident wave height. Indeed the work of MASON and HANSON (1989) could apply to the HB barrier beachface as HB often has a demarcation between an upper beachface comprising gravely sediments and a lower beachface of finer sediments with the gravely sediments having the steeper beachface slope.

6.5 Summary and Conclusions.

The breaking wave steepness has been shown to be a useful parameter when relating the morphodynamics of the beachface slope to the incident breaking wave and more importantly the changing beachface slope over time. The transverse profile can range from concave up, to linear, to convex up. This profile classification has a simple geometric measure based upon the right-angle triangle, or the relationship between area (x1=volume) and the vertical height and the length of the base of the beachface 'wedge'. Beachface erosion takes place when the wave steepness reaches some critical number, for example wave steepness > 0.01 and accretion when the wave steepness < 0.007. This is for the deep-water wave parameter and a similar criterion applies for the breaking wave steepness B_s.

Seasonal cycles of the MSG beachface cross-shore transverse profiles have two end member states: -

1). Dissipative, concave up, minimum sediment storage-maximum wave energy, storm, winter conditions. Large surf scaling parameter (ε) and small Iribarren ξ (surf similarity) number.

2). Reflective, convex up, maximum sediment storage-minimum wave energy, calm, summer conditions. Small surf scaling parameter (ε) and large Iribarren ξ (surf similarity) number.

CHAPTER 7 BEACH SURVEYS, CROSS-SHORE TRANSVERSE PROFILES.

7.1 Introduction.

The data set for this chapter represents some three years of sequential surveys obtained at approximately monthly intervals between 1998 and 2001; (three months are missing).

The aims of the Chapter are: -

1). Profile morphology; an example of possible seasonal configuration, and longer period morphology oscillations.

2). The profile relationships as defined by profile height, width, volume and the 'profile index' (the macro-profile types). This chapter explores some of the inter-relationships by a series of bivariate plots and as time series. Observations suggest that the morphodynamic changes of the southern HB beachfaces have well defined oscillations within the 'hydrodynamic zones' about MSL. For example, over a given time period of say 4 months as the HW ridge accretes the LW ridge and platform erode, and vise-versa with monthly regularity. This chapter sets out to show such 'oscillations' and where across the beachface the most and least topographic height changes take place,

3). The morphodynamic relationships of the surf scaling parameter (ε) and the Iribarren number (ξ), the profile slope (β) and wave steepness (B_s) are shown as bivariate and time series parameter arrays. The parameters selected are of two time scales, daily and monthly. This explores the importance of time scale to data acquisition. The morphodynamic parameters are for the Te Awanga Hall site.

7.2 Literature Review.

The seasonal cycle and the longer evolution of transverse profiles for sandy beaches have representation in the literature for Brazil (BITTENCOURT, et al., 1997) and Nag's Head, the North Carolina barrier (SOUTHGATE and MÖLLER, 2000). As a first approximation, HB may also have 'similar' cycles of morphodynamic evolution shown by changes of the cross-shore transverse profile and the breaking wave steepness. The morphodynamics are expressed by the beachface parameters measuring the height (Hc), width (S), and sediment volume (Q), and the relationship of these parameters and profile types (concave, linear or convex; ORFORD, 1986). The macro-profile types classification follows that proposed by ORFORD (1978) and CALDWELL and WILLIAMS (1985) for MSG beaches; also termed the beach profile shape index (FUCELLA and DOLAN, 1996) for the sand barrier at Nag's Head, North Carolina. As a second approximation selected lengths, or zones, of the beach profile can be linked to the hydrodynamics, and hence morphodynamic zones.

Appendix 8 is an attempt to define the profile parameter measurements for the HB. In this Chapter the HB sites had particular morphodynamic attributes. For example, Haumoana was initially erosive, with overwashing and a rollover barrier crest, and later became accretionary at the updrift side at a groyne construction. The relationship of the morphodynamics and the wave steepness is demonstrated by the linear wave steepness B_s (ORFORD, 1977). However, the relationship between wave steepness and beachface slope is not linear (BITTENCOURT, et al., 1997; SOUTHGATE and MÖLLER, 2000).

7.3 Profile Morphology. Examples of the Temporal Configurations.

Te Awanga Hall and Clifton are particular sample sites to represent the morphological states over a period of time, where time is firstly seasonal and secondly longer (an extended time frame).

Results. Seasonal.

Figure 7.1 is an equinoctial data sequence comprising six consecutive monthly cross-shore transverse profiles that can generally define the HB morphodynamic zones.

The data for each interval is a measure of a single profile that maps the morphology defined by topographic breaks of slope. Breaks of slope often signify other changes, for example gravel sizes and wave break. Over a number of intervals the topography changes and consecutive cross-shore transverse profiles maps the morphodynamics.

Figure 7.1 has a well-defined up-beachface morphology comprising the apron, step, platform (LW ridge), swash, high water ridge (HW ridge), and crest. It is also noticeable that at the breaks of slope that define the morphology both the vertical bed heights and cross-shore distances vary over time. The morphodynamics in this study are the vertical height changes at set cross-shore distances above a set datum (the datum is Mean Sea Level (MSL)).and are greater at the HW ridge and at the step, and are least at the crest.

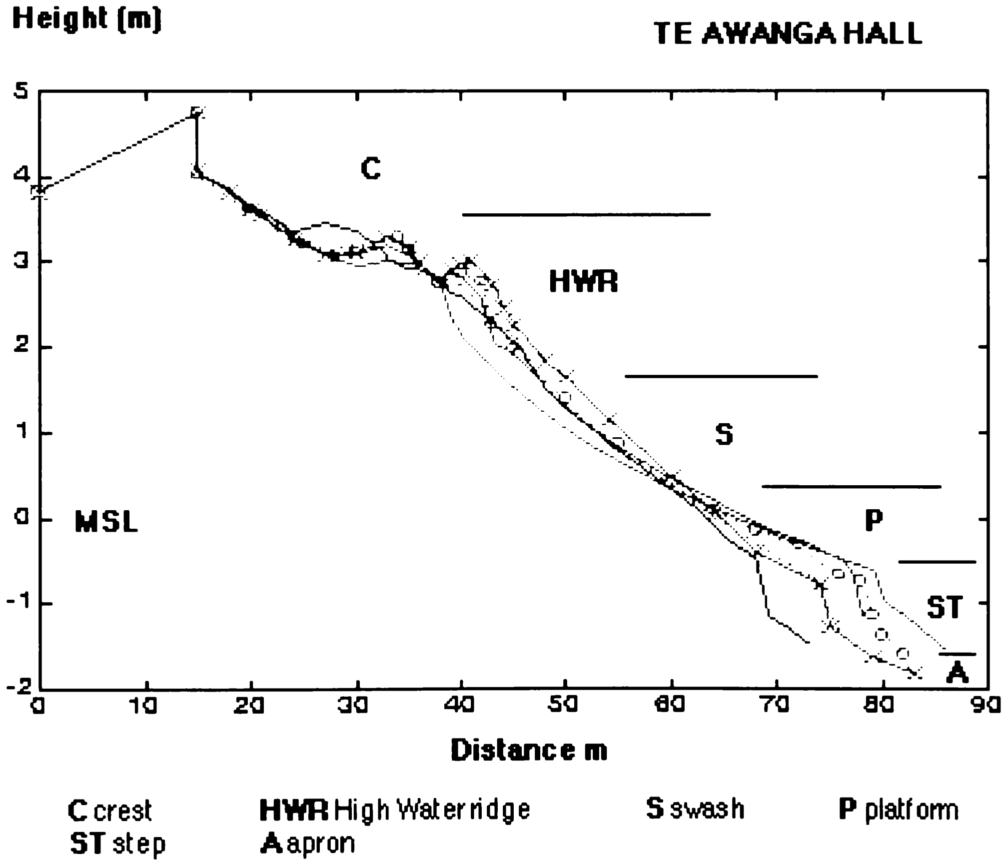


*Figure 7.1 Te Awanga Hall, seasonal profiles from 6 October 1998 to 16 March 1999, a 'summer' season. The major morphological shapes are defined by the transverse profile. The changes can have similar shapes that can define the morphodynamic responses of the beachface to events over a period of time. **MSL** is mean sea level.*

The vertical changes associated with the MSL are also less than at either the HW ridge or step and these least change distances (crest and MSL) each form a locus. Indeed the MSG locus appears to act as a hinge about which the morphology tilts, for example if the HW ridge is elevated, the platform is lower, and vice versa.

In this example the locus at the beach crest is fixed and defined by the seawall. A locus can therefore be defined by the least relative morphodynamic change (both? vertically and horizontally).

The HB morphodynamics correspond to the hydrodynamic zones defined as: -

Morphodynamic Zone	Hydrodynamic Zone
i). Crest.	Least active. Intermittent hydrodynamics usually characterised by wave induced currents as overwash and can have associated sedimentation as overwash. Can also be erosive where material is removed to either landward (overwash deposition) or to seaward (storm sapping).
ii). HW ridge.	Active at high water, characterised by wave overtopping and overwash. HW ridge can be either accretional, or erosive.
iii). MSL.	Active except for relatively short periods of low water (low tide).
iv). SA.	Sub-aqueous (SA) is continuously active and has complex water flow, for example can have fresh water issuing from the beachface.

Extended Time Frame.

It is possible to map a morphodynamic zone by a vertical height at a fixed cross-shore distance. By repeatedly surveying at that fixed distance a representation of the morphodynamics over time can be gained. This introduces the isopleth method (BITTENCOURT, et al., 1997; Figure 2, p 1143). The isopleth is a measure, at the same cross-shore distance, of vertical height change over time. In the following example (Figure 7.2) three isopleths represent the loci at MSL, the beach crest and the more changeable (and greater morphodynamic) HW ridge. Figure 7.2 demonstrates that the locus is not stationary over a prolonged period. As expected the HW ridge has greater vertical height changes and these can be either fluctuating or be continuous. There may possibly be a long cycle at MSL and the HW ridge over some 25 to 27 months as values cycle from a minimum to a maximum and return to a minimum.

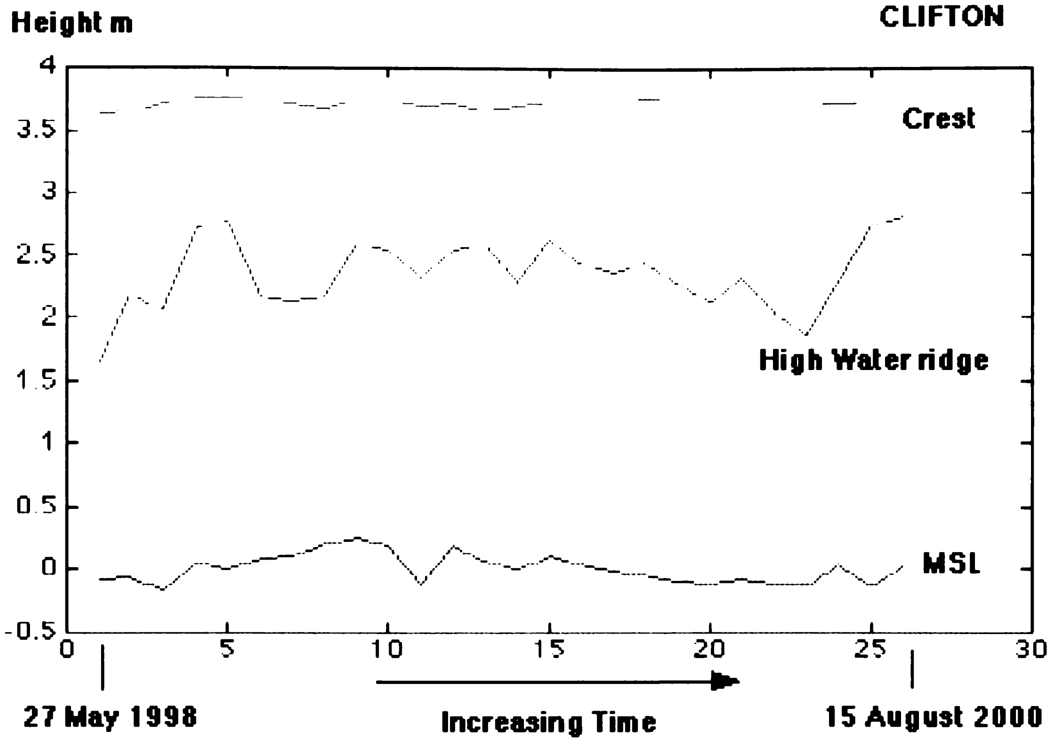


Figure 7.2 Clifton. Isopleths are the vertical height changes, measured from Mean Sea Level, at three select and fixed cross-shore distances. These isopleth represent the morphodynamic responses at three hydrodynamic zones namely beachface crest, the high water ridge (HW ridge), and mean sea level (MSL). The samples are approximately at monthly intervals.

Discussion.

The HB beachface morphodynamic changes over two time scales (seasonal and perhaps several seasons, 33 months) have some similarities. Over a relatively short six-month seasonal period the HW ridge maintained a similar ridge morphology, however the HW ridge can shift cross-shore. Simultaneously the MSL has a very small morphological change and therefore has some degree of morphodynamic stability so viewed as a locus.

In the longer time, the HB data could have a cyclic signature (of some 33 months) demonstrated by the isopleths for both the beachface crest and the MSL locus. SOUTHGATE and MÖLLER (2000) show the fractal properties of coastal profiles over a long time series (10.5 y) using profile data from Duck, North Carolina. The cyclicity appears at cross-shore morphodynamic zones where the self-organisation "can form repeated patterns at definite space scales and time scales", because of self-organisation processes for "self-organised criticality". In the SOUTHGATE and MÖLLER (2000) analysis, the time domain cross-shore geomorphology has zones of self-organisation characterised by "persistence", "antipersistent ", and "random". The persistent dune zone of Duck could correspond to the HB beachface crest. The Duck dune zone has short time scales as the time variation of the incident wave field is small since most waves have broken and have dissipated their energy. Hence, the dune zone time scale is in the order of 1 y to 20 months, and, in response to storms, the forced response attains greater levels than the "offshore bar zone". Indeed the offshore bar zone at Duck is an antipersistent zone. At Duck at the offshore bar zone the large waves have already broken, but the forcing is from the smaller broken and unbroken waves that occur most of the time and hence introduces the antipersistence.

There are possibly two antipersistent zones on the HB beachface, firstly at the HW ridge where the forcing is more random via run-up that can occur as a current swash and backwash, and as a breaking wave (as spilling, dissipating bore and plunging). Secondly, below MSL. At Duck below the shoreline, the outer bar absorbs most of the incident wave energy, and this could correspond to the HB beachface step that absorbs most of the breaking wave energy. The HB MSL could correspond to the shoreline at Duck. In HB at the MSL the wave energy is already depleted and there is almost continual accretion and erosion taking place simultaneously, or Brownian motion. The MSL stability, or "persistence" at Duck, is a result from large-scale accretion that tends to a seasonal pattern at the shoreline.

Similar fractal morphodynamic evolution is described for sand beaches in Brazil (BITTENCOURT, et al., 1997) where the strange attractors equate to a geomorphic stability (vertical bed height change) over a long period of time.

Hence, the active beachface zones can have selected morphodynamic responses that can have a persistent or antipersistent morphology where these zones relate to hydrodynamic zones. However, it is speculative to suggest the average beach profile shape relates to the average hydrodynamics, but as a first approximation these relationships are explored.

7.4 The Profile Relationships: The Shape and Beachface Parameters.

Beachface morphodynamics can be parameterised using a linear approach to represent the active beachface height (Hc), beach width (S), sediment volume (Q), and surface configuration (SONU and YOUNG, 1970). SONU and JAMES (1973) refer to sediment storage (Q), which is a characteristic of the HB barrier with frequent overwash sedimentation and subsequent storage of sediment landward of the beach crest. However, to examine the morphodynamics in HB the active beachface is defined by the cross-shore distances confined by a beach crest height Hc, and the beach width (S) where the transverse cross-shore profile intersects the horizontal line defined by the local datum about MSL.

SONU and YOUNG (1970); SONU and JAMES (1973) use field data from Nags Head, North Carolina and apply a transitional Markov model to describe a number of profile shapes ranging from concave up, linear and convex up. A similar description of beachface profiles was applied to MSG beachfaces in Wales (ORFORD, 1978; CALDWELL and WILLIAMS, 1985), based upon the active beach width and beach crest height (ORFORD, 1986), although ORFORD (1968) suggests the distinction between the beachface shapes concave up, linear and convex up is not well defined. FUCELLA and DOLAN (1996) propose a beach profile shape index, or 'profile index' (PI) to distinguish between the beachface shapes that occur in response to high seas events (wave steepness, in this instance defined as "maximum wave height^2/wave period"), based upon field data from Nags Head. The ORFORD (1978); CALDWELL and WILLIAMS (1985) and FUCELLA and DOLAN (1996) profile shape index relationships in a qualitative sense are: -

concave up	reflective
linear	linear
convex up	dissipative

It is possible to decompose and relate the beachface parameters for each HB sample site, since the sampling is synchronous, also each site has particular attributes, for example: -

1). Clifton is a supply and possibly rests on a firm bedrock base, and is erosional.

Te Awanga has two sites,

2). The Te Awanga Hall acting as a supply, and a control (can be easily viewed most days). It is usually the case where if Te Awanga Hall is undergoing 'erosion' with material transported off-shore, then the other sites may be following the same trend, but this is not always the case (see Chapter 10).

3). Also at Te Awanga is K2 (since redesignated as HB2 (HBRC)) where 'defenses' were installed in late 1972, with vertical rail irons and vehicle tyres. These defenses have since been 'upgraded' (in 2003) using waste soil from local roading works.

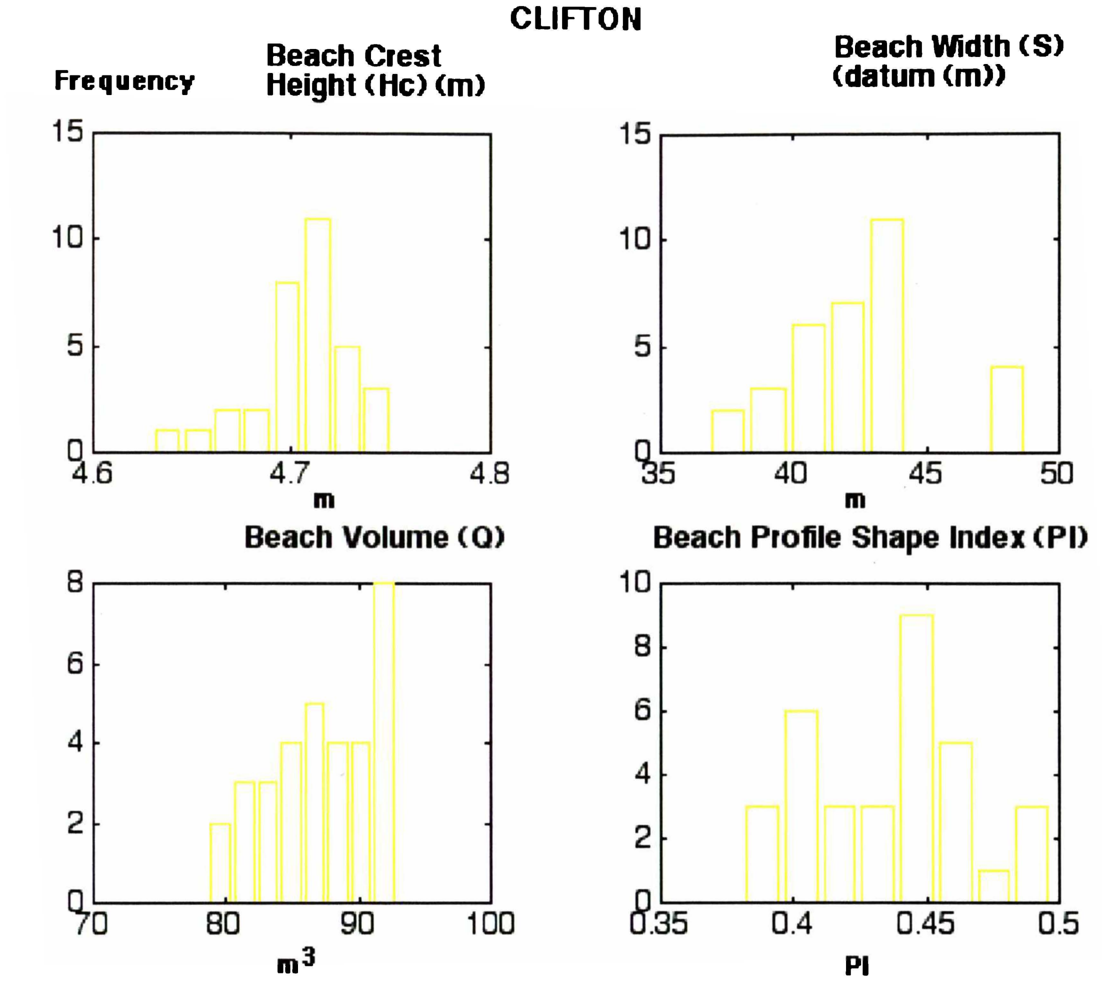
4). Haumoana began as a beachface undergoing landward migration accompanied by increasing overwash deposition. Later a groyne was built (early 1999) and the site became 'depositional'.

5). Marine Parade is a stable sink.

Results.

The beachface parameters explored to a common datum for each parameter are the beach crest height (Hc), the beachface width (S), the contained volume (Q), and the profile shape index (PI). The PI determines the beachface state of either concave, or convex or linear. (Appendix 8 shows the datum for each sample site). Parameter histograms for each sample site are located in Appendix 9. Table 7.1 summarises the range and averages of each parameter for each HB site. Table 7.1 also presents the PI parameters presented by ORFORD (1986) for a MSG beach and for the sand beach at Duck from FUCELLA and DOLAN (1996).

The beachface parameter histograms do not have Gaussian distributions, for example in Figure 7.3 the Clifton beach crest height (Hc) has positive (+ve) skewness, similarly the beach width (S) frequency is by-modal with an outlier representing 'extreme' beach widths (at some 48 m). Beachface sediment volume (Q) also has (+ve) skewness, induced by a strong maximum volume. As a consequence of the non-Gaussian parameters the profile shape index (PI) has a polymodal frequency and has (+ve) skewness with a pronounced maximum near to the mean value of PI (mean = 0.436).



Datum =4.5m composed of
MSL=3.513m, and
Napier Port datum=0.88m, and
Attainable=0.11m

n=33

$PI = \frac{Q}{Hc.S}$

where

PI = Profile shape Index

Q = sediment Volume

Hc = beachface crest Height

S = beachface width

Figure 7.3 Clifton. Frequency histograms of the active beachface morphodynamic parameters height (m), width (m), volume (m^3) and profile shape index (n=33; 28 June 1998 to 27 May 2001).

	CLIFTON	TEAH	K2	HAU	MARINE PARADE
Hc					
min	4.63	3.76	3.06	3.17	6.24
max	4.75	4.66	3.93	5.47	6.49
Ave	4.71	4.25	3.48	4.88	6.41
S					
min	36.80	38.20	22.50	26.80	61.80
max	48.80	49.00	35.10	62.20	69.70
Ave	42.64	42.39	28.93	49.28	65.79
Q					
min	78.75	81.03	33.54	40.57	190.59
max	92.82	104.17	54.12	149.37	226.89
Ave	87.197	90.29	43.76	115.64	208.93
PI					
min	0.381	0.433	0.366	0.324	0.452
max	0.497	0.591	0.519	0.555	0.536
Ave	0.436	0.504	0.437	0.459	0.496

n=33, each site approximately monthly intervals

Active beachface - to local datum

Hc	crest height	(m)
S	width	(m)
Q	volume (profile area. 1)	(m^3)
PI	profile index	

Profile index

(FUCELLA and DOLAN, 1996)

0.72	convex	summer
0.5	linear	
0.37	concave	winter

(ORFORD, 1986)

0.67	convex	summer
0.5	linear	
0.45	concave	winter

Table 7.1. The minimum, maximum and average parameter values of the southern Hawke Bay active beachface crest height (Hc), width (S), sediment volume (Q) and profile index (PI).

Discussion.

The parameter histograms (Figures 7.3; Appendix 9) can include outliers and more frequently polymodality. At Haumoana, the parameter changes have links to the construction of a groyne.

The range of parameters (Table 7.1) give some measure of the morphodynamics, for example generally the range of crest height (Hc) is small (Clifton, Hc range 0.12 m) but at Haumoana, it is much greater (Hc range 2.3 m). In fact, Haumoana has the largest range of all parameters and characterises the construction of a groyne just downdrift of the cross-section line. Marine Parade has the second greatest sediment volume (Q) change but the least beach width (S) and profile index (PI) change.

These relationships of (Q) and PI are further explored in the next section.

7.5 Beachface Relationships of Sediment Volume and Profile Index.

The following subsections examines the relationship between sediment volume change (dQ) and the profile index (PI) at sampling intervals firstly as bivariate plots and secondly as a time series.

Results, Bivariate Plots of the Changes of Sediment Volume and Profile Index.

Bivariate plots of the parameters dQ and PI may indicate some particular characteristics of the sample sites, for example the overall nature of a beachface, where these are known to be erosional (Clifton), or depositional (Marine Parade) or have changed from erosional to depositional (Haumoana - groyne construction).

Figure 7.4 depicts two example sample sites, the erosional (supply) Clifton and the depositional (sink) Marine Parade, Appendix 10 reproduces similar bivariate plots for the remaining sites.

Inspection of these bivariate plots and Table 7.1 indicates the parameters have three classification classes.

For example the PI range is generally from low (PI < 0.1); to mid-range (PI 0.1 to 0.2), and to high range PI (PI > 0.2); this places: -

1). Low range Marine Parade (0.084);
2). Mid-range Clifton (0.116); Te Awanga K2 (0.153) and Te Awanga Hall (0.158)
3). High range Haumoana (0.231).

Similarly, dQ can be classified as: -

1). Low range (dQ < 20 m^3/m) Clifton (14.07 m^3/m)
2). Mid range (dQ 20 to 30 m^3/m) with Te Awanga Hall (23.14 m^3/m), and Te Awanga K2 (20.58 m^3/m).
3). High range (dQ > 30 m^3/m); with Haumoana (108.8 m^3/m) and Marine Parade (36.3 m^3/m).

The profile shapes (concave up, linear, or convex up) have a range at each site and based upon the classifications of FUCCELA and DOLAN (1996) and ORFORD (1986) then: -

Beachface shape	Profile Index
linear	0.5
concave up (dissipative)	0.35
convex up (reflective)	0.67

In summary the morphodynamic beachface 'slopes' for the HB sites are: -

i). Clifton	linear-dissipative (linear-concave up).
ii). Te Awanga Hall	linear-dissipative (linear-concave up).
iii). Te Awanga K2	linear-dissipative (linear-concave up).
iv). Haumoana	linear-dissipative (linear-concave up).
v). Marine Parade	linear (linear).

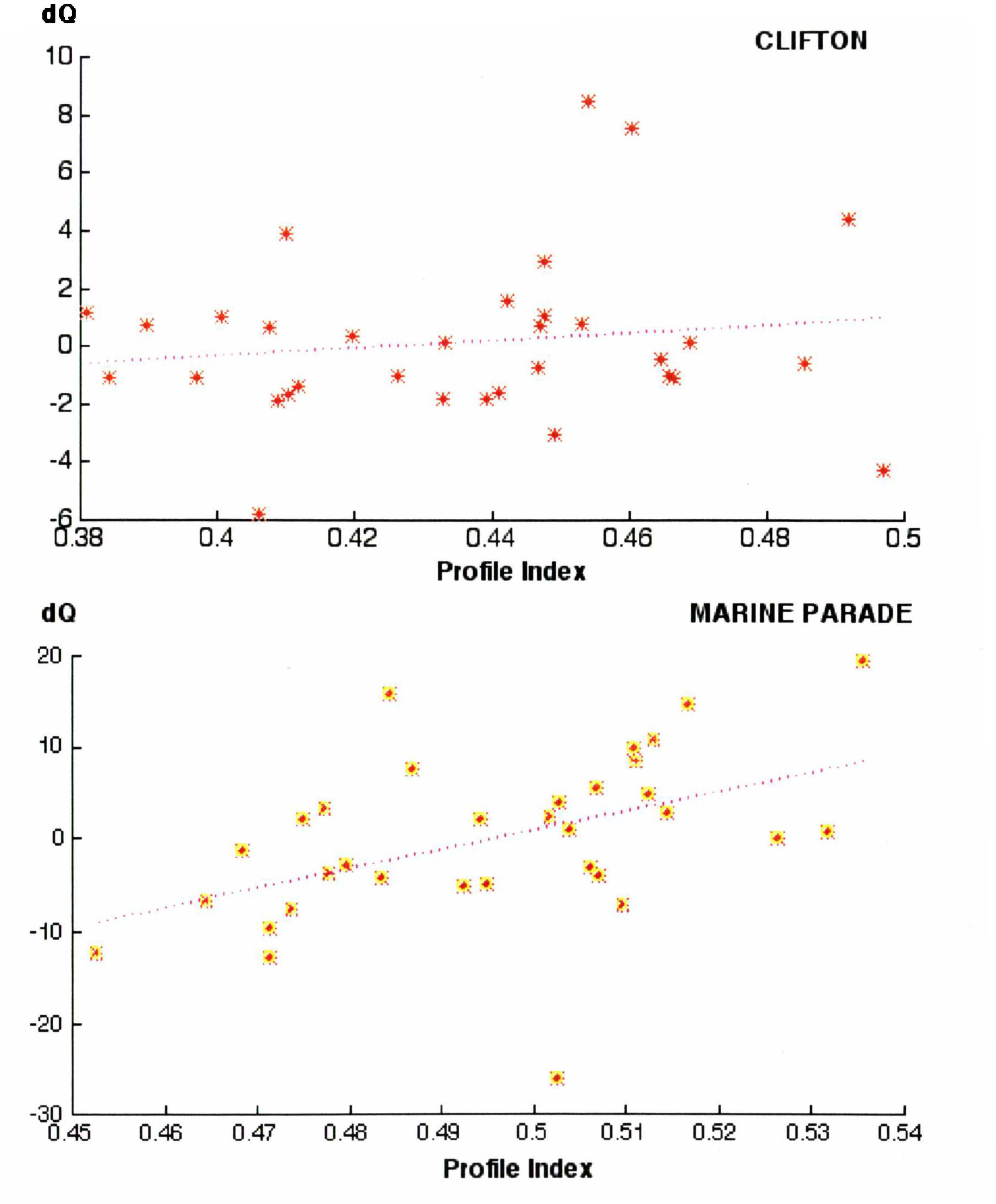


Figure 7.4. Clifton (supply, erosive) and Marine Parade (sink, depositional). Bivariate plot of active beachface intersample sediment volume change (dQ m^3) and the profile index (PI). Data June 1998 to May 2001, n=33. The linear regression (SYSTAT) for Clifton R^2=0.5%, and for Marine Parade R^2=0.1%.

Table 7.2 gives a morphodynamic classification: -

			RANGE			
Parameter	LOW		MEDIUM			HIGH
PI	MP	Clif	TAK2	TAH	Hau	
dQ	Clif	TAH	TAK2		Hau	MP

PI	Profile Index
dQ	Sediment volume change m^3

Clif	Clifton
TAH	Te Awanga Hall
TAK2	Te Awanga K2
Hau	Haumoana
MP	Marine Parade

Table 7.2. Semi-quantitative morphodynamic classification for the southern Hawke Bay sample sites based upon intersample sediment volume change and beach profile index. (Classification boundaries in text).

There are two broad patterns of bivariate plot data scatter, the overall shape of the data scatter, and the relationship between the parameters as a regression (a linear least squares fit).

The data scatter patterns (Figure 7.4; Appendix 10 no linear regression fit, the relationships fit is by eye) divide into two broad categories. Firstly, either a broad scatter, for example Haumoana (Appendix 10), or secondly, as a narrow elongate cluster, for example Marine Parade.

For Clifton, Te Awanga Hall and Te Awanga K2 it appears that as the beachface PI becomes increasingly reflective so the data scatter increases. This infers that the reflective beachface has greater extremes of dQ.

A linear regression fit, or visual estimate, of the bi-parameters for each site, Figure 7.4; Appendix 10, indicates three broad bivariate relationships of the linear gradient fit, either steep or near flat. Marine Parade has a steep positive relationship indicating that as the beachface departs from concave up to linear and towards convex up so the sediment volume change becomes increasingly more positive and the beach more depositional. The flatter gradient, for example Clifton shows a wide range of the sediment volume change as the beachface becomes linear from concave up. Consequently, more sediment volume changes remain negative (erosional). Thirdly, Te Awanga K2 has a negative linear gradient fit, suggesting as the beachface changes from concave up to linear the sediment volume changes becomes increasingly –ve ('erosional').

Results, Changes of Sediment Volume and Profile Index as Time Series.

The sampling period is from June 1998 to May 2001. The parameters (intersample sediment volume change dQ and profile index PI) are viewed as a time series over this sampling period as (1) changes, to view what the parameter changes are as sampling progresses, and (2) drift, or the long term trend(s), and are these similar or not for all beaches?

Parameter (Change of Sediment Volume (dQ), and Profile Index (PI)) Changes.

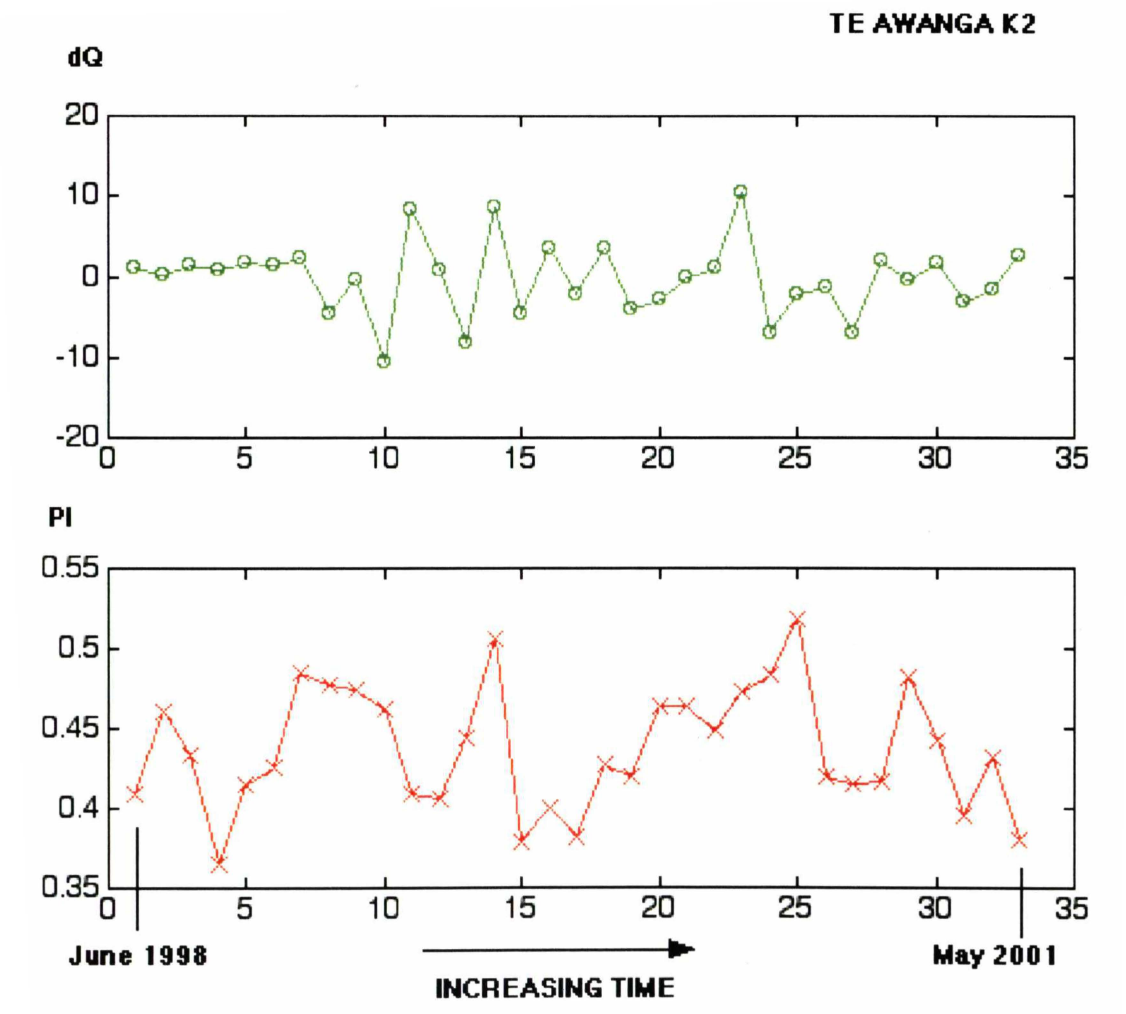
Similar to gravel sizes and forms there are oscillatory or continuous series of parameter change over the sampling period. As an example, Figure 7.5 shows the parameters dQ and PI as a time series for Te Awanga K2. (Appendix 11 shows the other synchronous sample site time series).

Figure 7.5 shows: -

1). A steady small range dQ oscillating (T = 1 to 7) which then successively increases in amplitude (T = 7 to 11) before shifting into a continuous series, decreasing dQ (T = 11 to 13). The longest continuous sediment volume change is T = 19 to 23.

2). The PI series has an initial oscillatory period (T = 1 to 3) that become more continuous T = 4 to 7 and 7 to 12.

There appear to be few direct relationships between dQ and PI, for example if the profile sediment volume change increases then the profile shape becomes more reflective. It is possible, indeed likely, that this depends on where across the profile the sediment deposition (or erosion) takes place, for example at the step and platform, and this is explored in Section 7.6.



dQ Sediment volume change (inter survey)
PI Profile index

Figure 7.5 Te Awanga K2. Changes of sediment volume (inter survey volume changes dQ m^3) and beachface profile index (PI) as time series, from June 1998 to May 2001 (n=33).

However, associations of the parameters do occur and for maximum spikes, where both the dQ and the PI parameters have similar parameter increases. For example, at two separate time intervals, firstly the first spike at T = 7, has a maximum sediment volume increase and a profile shape shift to linear, from dissipative; the second is at T = 14 where the dQ increases and the PI increases and changes to linear from dissipative.

Contrary associations are also present at Te Awanga K2, for example T = 11, where the beachface PI decreases, becomes dissipative from linear and simultaneously the sediment volume increases substantially.

Parameter (Change of Sediment Volume (dQ), and Profile Index (PI)) Drift.

Over the sampling period (June 1998 to May 2001), the parameters dQ and PI can have drifts, or long sampling period trend(s). For example, Haumoana (Appendix 11) has a long trend suggesting the profile shape has drifted from dissipative and is becoming linear.

A quantitative description can be arranged as: -

	dQ	PI
SITE		
CLIFTON	-0.0399	0.0030
TE AWANGA HALL	-0.0726	-0.0030
TE AWANGA K2	-0.0348	0.0010
HAUMOANA	-0.2452	0.0034
MARINE PARADE	0.0024	-0.0008

Table 7.3. Long trend drift of parameters of volume changes (dQ m^3) and profile index (PI). (Least squares regression gradient coefficients).

Parameters in Table 7.3 show that the -ve dQ is an erosional sediment volume change. Similarly the -ve PI suggests a drift of profile shape from linear towards dissipative (concave up). dQ +ve suggests sediment volume changes are depositional, and +ve PI suggests the profile shape is becoming more linear, from dissipative.

Depending upon the regression gradients the sites can be grouped into: -

A). Clifton, Te Awanga K2, Haumoana	erosional; profile becoming linear
B). Te Awanga Hall	erosional; profile becoming dissipative
C). Marine Parade	depositional; profile becoming dissipative.

These drifts suggest that the temporal relationships of the sites are not all similar. It should be noted that the regression gradients (trends) vary, with Marine Parade having the flattest (least temporal drift) gradients of both dQ and PI. Haumoana has the greatest dQ trend followed by Te Awanga Hall. The greatest PI drift is Haumoana followed by Clifton.

Discussion.

SONU and JAMES (1973) suggest Nag's Head sand barrier can vary between three beachface profile geometries: concave up, linear, and convex up. ORFORD (1986) applied a similar profile classification to the Llanrhystyd MSG barrier in Wales and noted the beachface rarely has a convex up profile shape. This beachface profile geometric classification is applied to the HB MSG active beachfaces. The HB beachface transverse cross-shore profiles also have a profile index type that is restricted between convex up to linear. Interestingly the lack of convex up geometry may be a general characteristic of MSG beaches. ORFORD (1986) also suggested the profile is process related where the gravel sizes separate out (are sorted) and dominate the "beach ridge height" from a swash run-up process. This profile-sediment sorting-swash process also applies to the HB HW ridge. Other dimensions of the barrier are also process related, for example, the longshore ridge (crest) height and the HW ridge are longshore wave energy gradient and refraction related. Similarly beach width is process related with the least gravel beach width related to foreshore sand build up that can occur in the HB inshore across the apron. This beach width relationship can be difficult to determine. Generally, in HB, the beach width relates to platform variation and processes, for example high seas can downcombe the HW ridge gravels that subsequently transport to the platform and deposit and therefore increase the beach width.

ORFORD (1986) statistically tested the Llanrhystyd Beach, Wales, by viewing the covariance of the sediment volume regressed against the beach width. ORFORD (1986) concluded there was no significance of the 8 regression gradients, but the pooled gradient estimate was significant, hence suggesting the visual sub-divisions to compare Llanrhystyd to Nag's Head profiles "was not a valid proposition".

A chosen value of h_{max} can be a function of the beach surface configuration and "excessive local deposition" defined by "geometric properties of the beach profile" (CALDWELL and WILLIAMS, 1985). Therefore, in HB the vertical height at an arbitrary distance from a BM can represent a morphodynamic feature. For example the HW ridge (ignoring the lateral migratory nature of the HW ridge, Figure 7.1). CALDWELL and WILLIAMS (1985) warn that the large variations of sediment facies and morphology occurring in close spatial proximity precludes an extended spatial sampling to explore facies (and morphogenic) models. HB has demonstrable patterns associated on a greater spatial scale. Tables 7.2 and 14.3 show similarities and differences of the sample sites in both bivariate and time scale space. Similarities observed for Te Awanga K2 (Figure 7.5) and Haumoana (Appendix 11) have early slight oscillatory dQ that at T = 7 start to oscillate with greater amplitude. These departures attaining greater amplitude are coincident with known 'effects' (structures), namely the rebuilding of a vehicle tyre 'seawall'.

7.6 Profile Morphodynamics and Cross-shore Topographic Changes.

Until now, it is not known where on the transverse profile the topography changes take place. This is because dQ is a bulk measure and PI assumes a smooth (usually curved) surface with no breaks of slope, or, where these breaks of slope occur. In this section, the temporal positions of the cross-shore topology for two sites demonstrates the general similarity of the morphodynamic responses and secondly at one site to show the relationship between the topographic changes and the breaking wave.

The profile data sets represent a summer season at two sites, Clifton the summer 1998 to 1999 and Marine Parade, summer 1999 to 2000. Summer seasons can have weather changes associated with inshore breaking waves and profile changes. The example profile data sets (Figure 7.6) comprise six profiles collected at monthly intervals. Each data set is averaged to detrend the set. The result indicates where the cross-shore gain and loss of sedimentary material take place. The Clifton data set examines in detail the topology (Figure 7.6) and the wave climate.

Figure 7.6 shows examples of the cross-shore morphodynamics for the two HB sample sites Clifton and Marine Parade have similar outline shapes despite being from separate sampling seasons, however, the dimensions differ. Marine Parade beach has the greater width and the least vertical height variation when compared to Clifton. The beachface widths, between the active crest and the sub-aqueous step, are Clifton 40 m and Marine Parade at 55 m. Both sites have vertical height changes at similar morphodynamic features; these features appear to alternate in the cross-shore direction between +ve and -ve vertical heights. The greater vertical height changes are greatest at the beach crest; HW ridge and slightly less at the sub-aqueous platform. The least vertical height change or 'narrows' are at MSL and between the HW ridge and the beach crest. The greatest vertical height variation at both sites is at the HW ridge with Clifton at some ± 0.6 m and Marine Parade at some ± 0.5 m.

In more detail Figure 7.7 shows two characteristic topographic oscillations where these can be related to the breaking wave, firstly the storm ridge oscillation, and secondly the HW ridge-platform oscillation.

The Storm Ridge Oscillation.

The storm ridge oscillation is observed between the first two time intervals marked as '1' and '2' on Figure 7.7 (6 October 1998 and 14 November 1998). At some 20 m cross-shore distance the 6 October storm ridge zone was accretional and by 14 November became erosional with the removal of some 0.7 m of sediment (A to A' on Figure 7.7), however, with the notable exception of an accretional ridge at 21 m.

The linear wave characteristics attributed to this erosion and the ridge accretion occur on two occasions. These occasions are (i) a three-day event and (ii) a one-day event.

i). Three day event. Between 11 and 14 October 1998 (mid October) the wave parameters were: -

Average wave steepness B_s > 0.025 (peak 0.042)

Maximum H_b = 2.5 m

Maximum T_b = 14 s.

This was an erosional event.

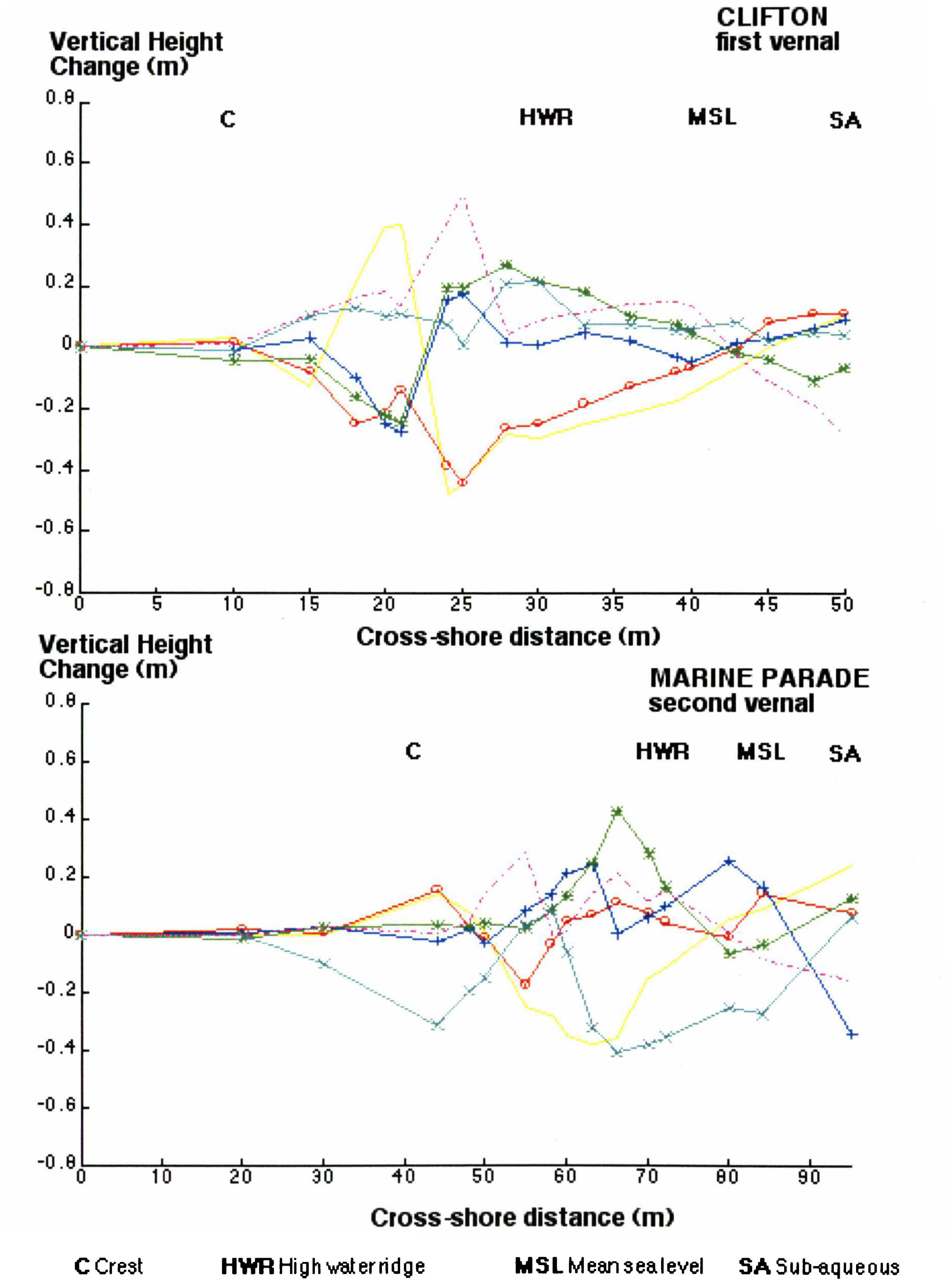
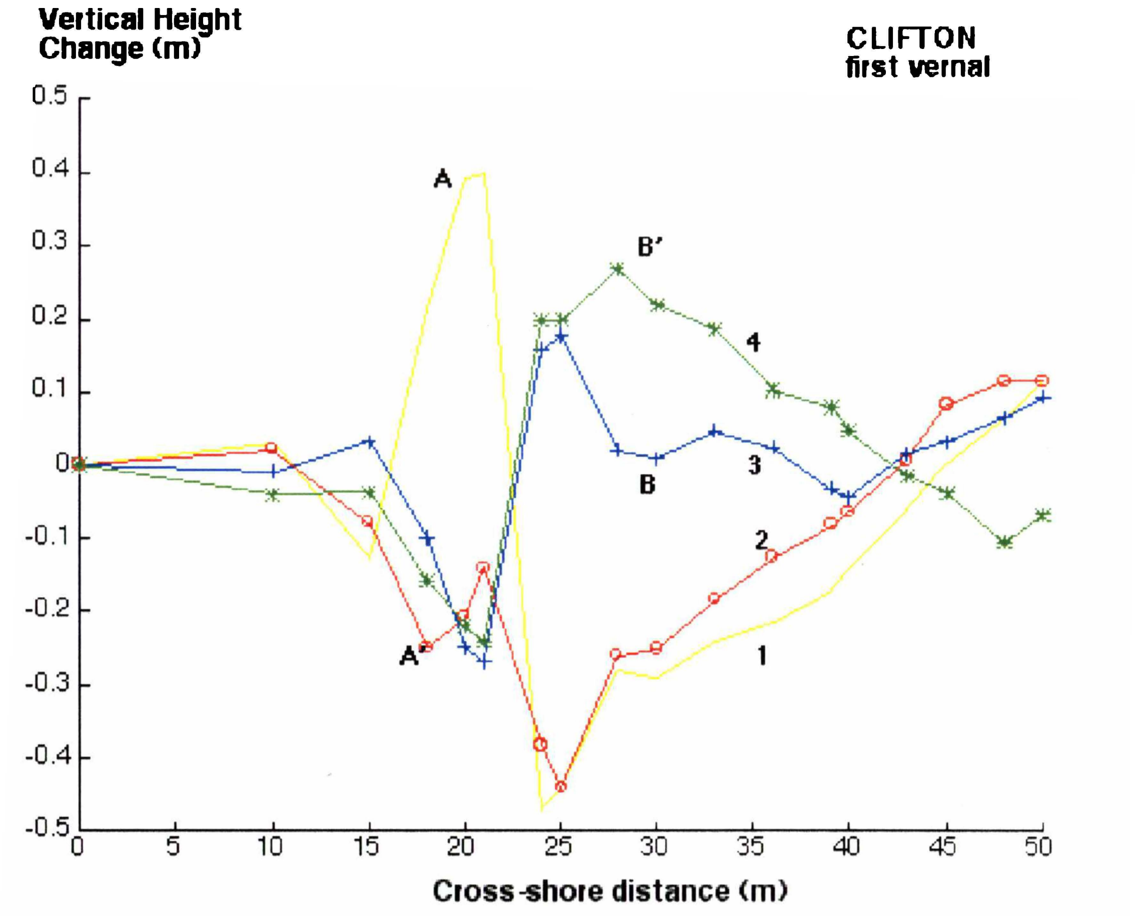


Figure 7.6 example cross-shore morphodynamics for two sample sites, Clifton and Marine Parade. Depicted are the residual, detrended exquinoxial season cross-shore transverse profile topographies (colours match synchronous 'monthly' sample dates).



Time series **1** 6 October 1998 **2** 14 November 98 **3** 13 December 98 **4** 4 January 1999

Morphology oscillation **A to A'** storm ridge erosion
B to B' high water ridge deposition and erosion of platform

Figure 7.7 Clifton. Detrended first vernal, first four profiles. The first four dates (time series) are examples of the morphodynamic oscillations at the storm and high water ridges.

ii). One day event. On 4 November 1998 a short pulse high seas event attained the wave parameters of: -

$B_s > 0.055$

$H_b = 2.0$ m

$T_b = 8.0$ s

This was an accretional event.

Prior to this small accretional event on 4 November the storm event of 11 to 14 October 1998 eroded the storm ridge by a process of ridge sapping via wave run-up swash. The accretional ridge at 21 m (cross-shore distance) on profile **2** (14 November) was deposited on the 4 November. The event was a short pulse transport of gravely sediments up the beachface. Because the event was a pulse, it is likely the sediments were derived locally from the inshore and possible from those eroded previously in mid October.

The HW Ridge Oscillation.(Figure 7.7)

Between the dates 13 December 1998 and 4 January 1999, the HW ridge extended too seaward (B to B') as material welded onto an antecedent HW ridge deposited between 14 November and 13 December 1998.

The wave climate over the period (B to B') had two characteristic high-energy wave events. These are: -

i). Two-day event. The wave parameters for 29 and 30 December 1998 were: -

Average $B_s > 0.040$
Maximum $H_b = 1.0$ m
Maximum $T_b = 9$ s.

ii). One-day event. On 3 January 1999 a short pulse high seas event attained the wave parameters of: -

$B_s > 0.06$
$H_b = 1.6$ m
$T_b = 7.0$ s.

Above MSL, the deposition was in the form of an accretionary wedge against an antecedent HW ridge. The antecedent HW ridge deposited between profile '2' and '3', namely between 29 November to 3 December when the breaking wave height (H_b) attained 4 m and period (T_b) 9 s. Below MSL the sub-aqueous platform and step oscillated noticeably. On 13 December 1998, the platform was accretional, but on 4 January 1999 the profile step was in an eroded state, and this is an example of antipersistent morphodynamics. The HW ridge oscillation is clearly defined by the relative height differences at the cross-shore distance of 25 m. For example, profiles '1' and '2' are erosional whilst profiles '3' and '4' are accretional. These are also antipersistent morphodynamics exemplified by large-scale vertical height changes. It is also worth noting the small vertical height changes about MSL, a persistent morphodynamic feature.

Discussion. The Cross-shore Topology of the Hawke Bay Beachface.

Over a summer season, the HB cross-shore profiles can exhibit a similar topology at more than a single site (Figure 7.6). Further, the topology can describe the morphodynamics (Figure 7.7). Observations suggest the morphodynamic processes can produce similar results and within fairly well defined topographic boundaries.

The HB general cross-shore topology from the Bench Mark to seaward can be broken into five shapes reproduced diagrammatically in Figure 7.8. There are three zones of greater topographic height changes corresponding to the beach crest (1), HW ridge (2) and the platform (3). Between these maxima are zones of relatively less height change corresponding to the storm ridge (2) and Mean Sea Level (4).

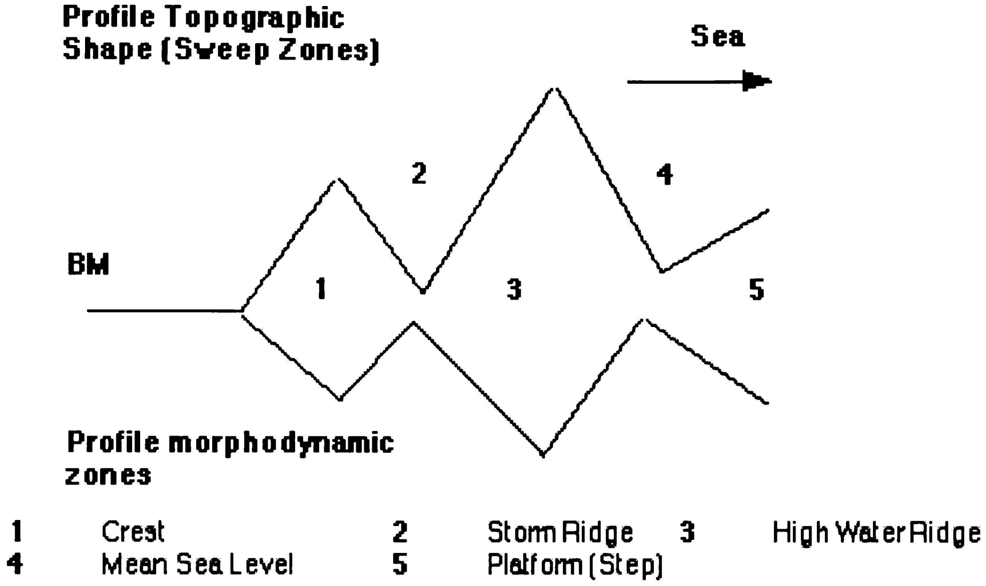


Figure 7.8 The general topographic envelope describing the morphodynamic changes of the Hawke Bay cross-shore transverse profiles. The envelope is obtained by detrending a seasonal profile data set. The result is a topographic change sequence that has a characteristic outline shape.

These two basic topological zones could be similar to zones of antipersistence (greater vertical height change) and persistence (less vertical height change). The greatest height changes are at the HW ridge where the maximum sediment accumulation and erosion take place. These greater height changes invariably take place over a season and relate to both incident waves and an antecedent morphology. In these examples the "excessive local deposition", or indeed erosion defined by local "geometric properties of a beach profile" (CALDWELL and WILLIAMS, 1985) relate to sediment transport in energetic environments. With the HB example in the first period October 1998 to November 1998, there is sufficient sediment in the inshore system for deposition across the active beachface with a concentration (of gravels) at a HW ridge at the swash run-up limit.

The second period (December to January) suggests reworking and cannibalism of the beachface platform that possibly supplies sediments to the HW ridge. This marks the second most frequent beachface morphodynamic change where the HW ridge zone builds vertically as the lower beachface platform 'erodes', and vise-versa as the HW ridge erodes the platform accretes.

7.7 The Morphodynamic Relationships: Sediment Volume Change (dQ), Profile Index (PI), Breaking Wave Steepness (B_s), Surf Scaling Parameter (ε) and Iribarren Number (ξ).

These parameters are applied to the Hawke Bay beachface, firstly as bivariate plots and secondly as time series.

1). FUCELLA and DOLAN (1996) used field data from Nag's Head to demonstrate relationships between wave steepness (B_s) and the active beachface configuration (sediment volume, Q; profile index PI).

2). The surf scaling parameter. FORBES, et al. (1995) suggest this parameter could have a useful relationship to the morphodynamics of the migrating MSG barriers on the Canadian northeast coast. The surf scaling parameter has also proved a useful morphodynamic parameter for classifying the morphodynamics of Australian beaches (SHORT, 1979; WRIGHT, et al., 1979; HUGHES and COWELL, 1987).

3). The Iribarren number. ORFORD (1977) proposed a method of differentiating storm MSG beach profile type (winter-summer) using a linear breaking wave steepness (B_s), and utilised in an Iribarren number BATTJES (1974) context.

The bivariate distributional plots and time series data period is January to May 2001, for the Te Awanga Hall site. The beach slope (β) is between High and Low tide measured on the day of profiling. Note, there is a temporal schism in this data set since most data is monthly, but the first two data are daily. The reason for this is to demonstrate that the daily variation can be in the same order as that occurring over longer time intervals.

Results, Bivariate Plots.

1). As a bivariate plot Figure 7.9 shows the relationships of dQ and Bs. Similarly Figure 7.10 shows that of PI and B_s. The change of sediment volume dQ appears to be a function of B_s where the negative changes of dQ occur at a $B_s < 0.026$ and the boundary for positive dQ occurs at $B_s > 0.03$. PI appears mostly constrained between PI = 0.42 and 0.48 for most breaking wave steepness B_s. The data scatter does have outlier points that relate to a specific high seas event.

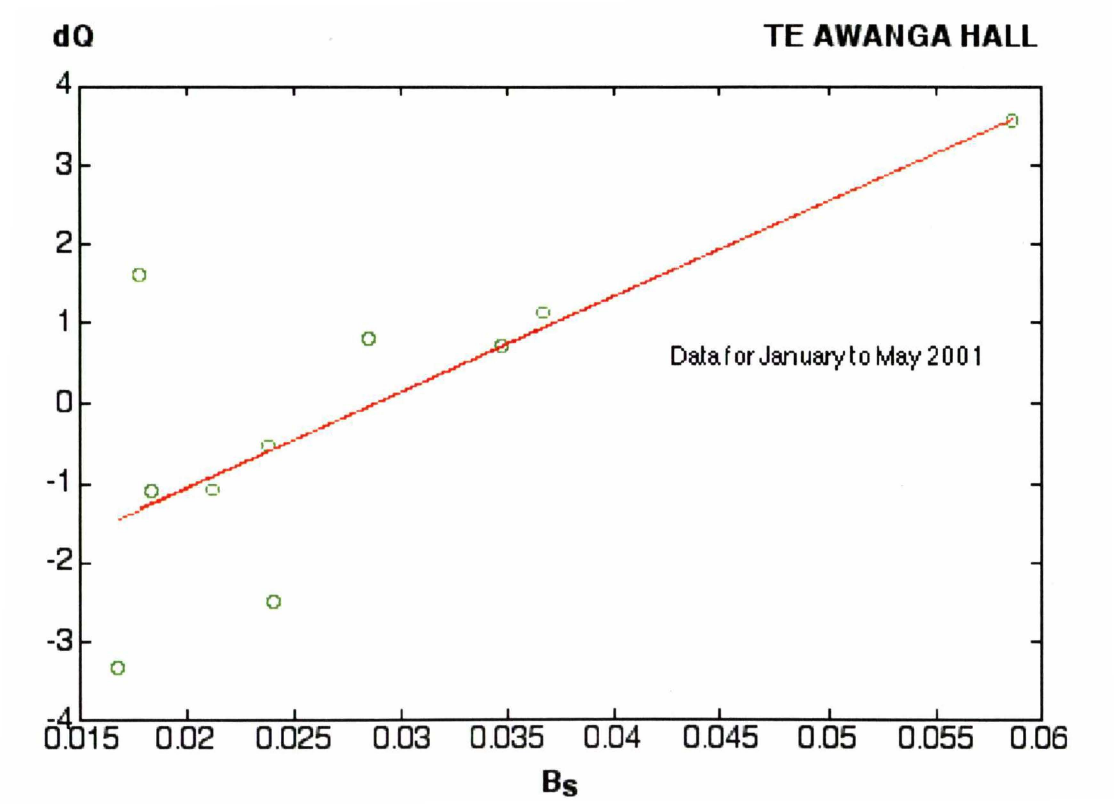


Figure 7.9 Te Awanga Hall. Bivariate plot of breaking wave steepness (B_s) and the change of sediment volume (dQ). The linear regression (STATISTICA) for Te Awanga Hall R^2=55.44%.

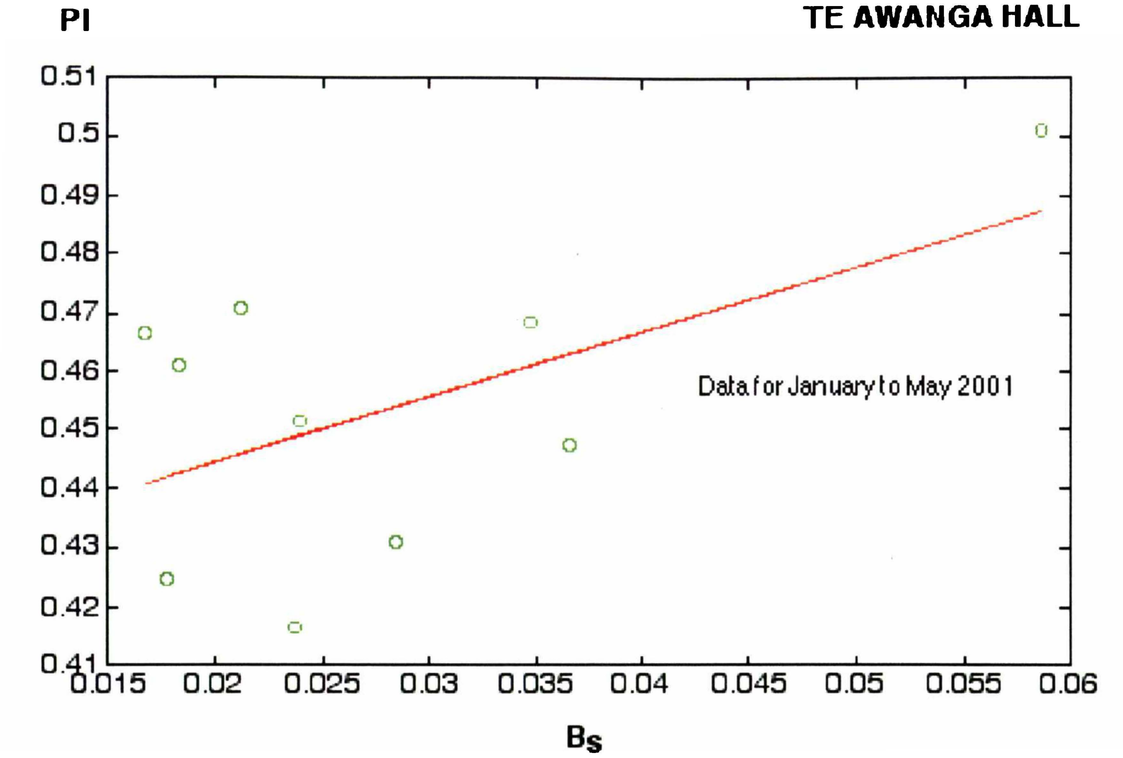


Figure 7.10 Te Awanga Hall. Bivariate plot of breaking wave steepness (B_s) and the profile index (PI). The linear regression (STATISTICA) for Te Awanga Hall R^2=30.71%

2). The surf scaling parameter (ε). Figure 7.11 demonstrates the relationship between the morphodynamic change and the wave energetics. The wave energies appear constrained with **A** (Figure 7.11) values between 0.1 to 0.55, with an outlier at 1.33. The morphodynamic parameter **B** (Figure 7.11) is more variable and splits into two groups firstly 0.06 to 0.09 and secondly 0.1 to 0.13, with an outlier. The outlier is the known high-energy event.

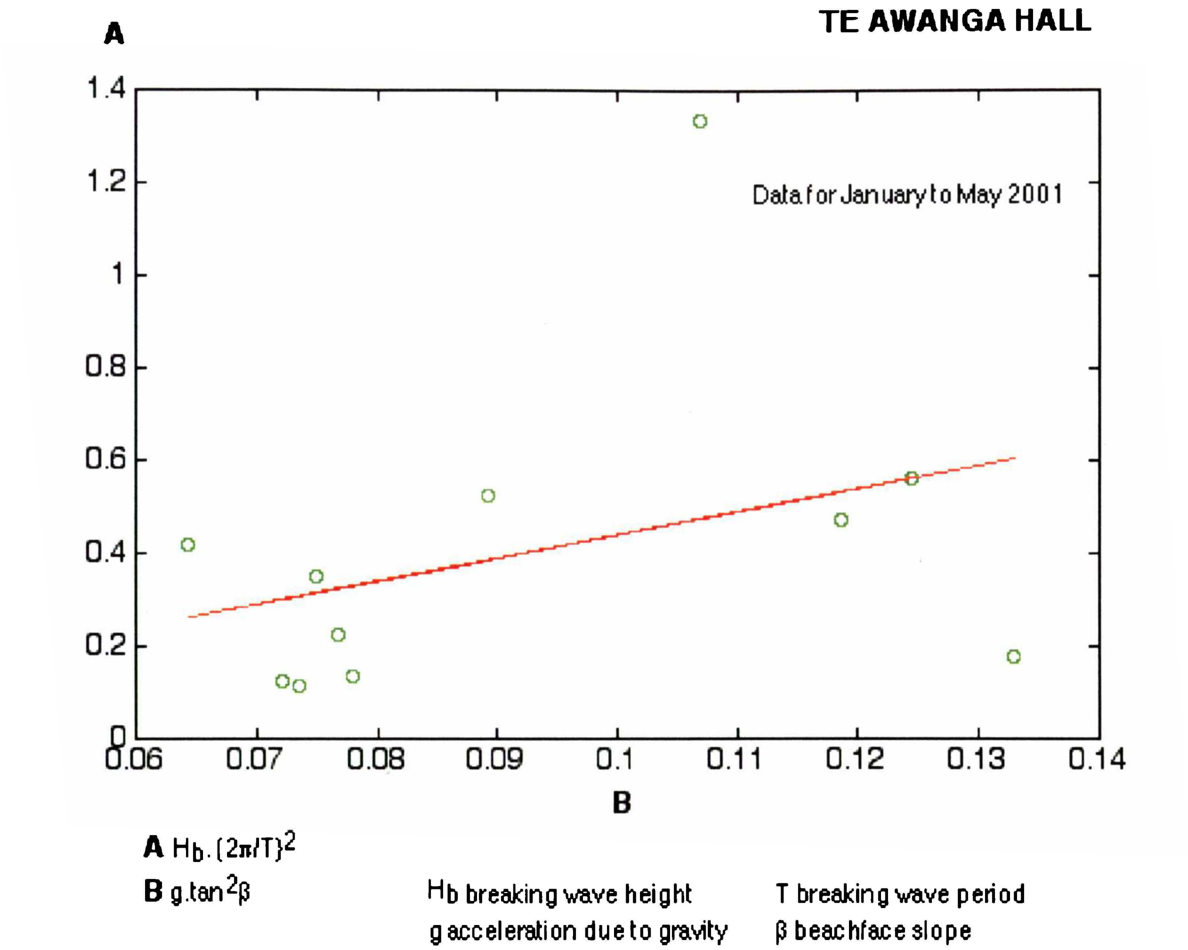


*Figure 7.11 Te Awanga Hall. Surf scaling parameter (ε). Bivariate plot of beachface morphodynamics (**B**) and the wave energetics (**A**). The linear regression (STATISTICA) for Te Awanga Hall* R^2*=9.67%*

3). The Iribarren number (ξ). Figure 7.12 is a bivariate plot of the relationship of β and B_s. The data scatter can be split into $0.03 < B_s > 0.03$, with an outlier near $B_s = 0.06$. The morphodynamic response, β, splits the parameter scatter into two groups $0.1 < \beta > 0.1$. Generally with low B_s ($B_s < 0.026$) the beachface slope can be either steeper or flatter (about $\beta = 0.1$), suggesting for low wave steepness the beachface can be either 'reflective' ($b > 0.1$), with collapsing wave types or dissipative ($\beta < 0.1$) with surging wave types.

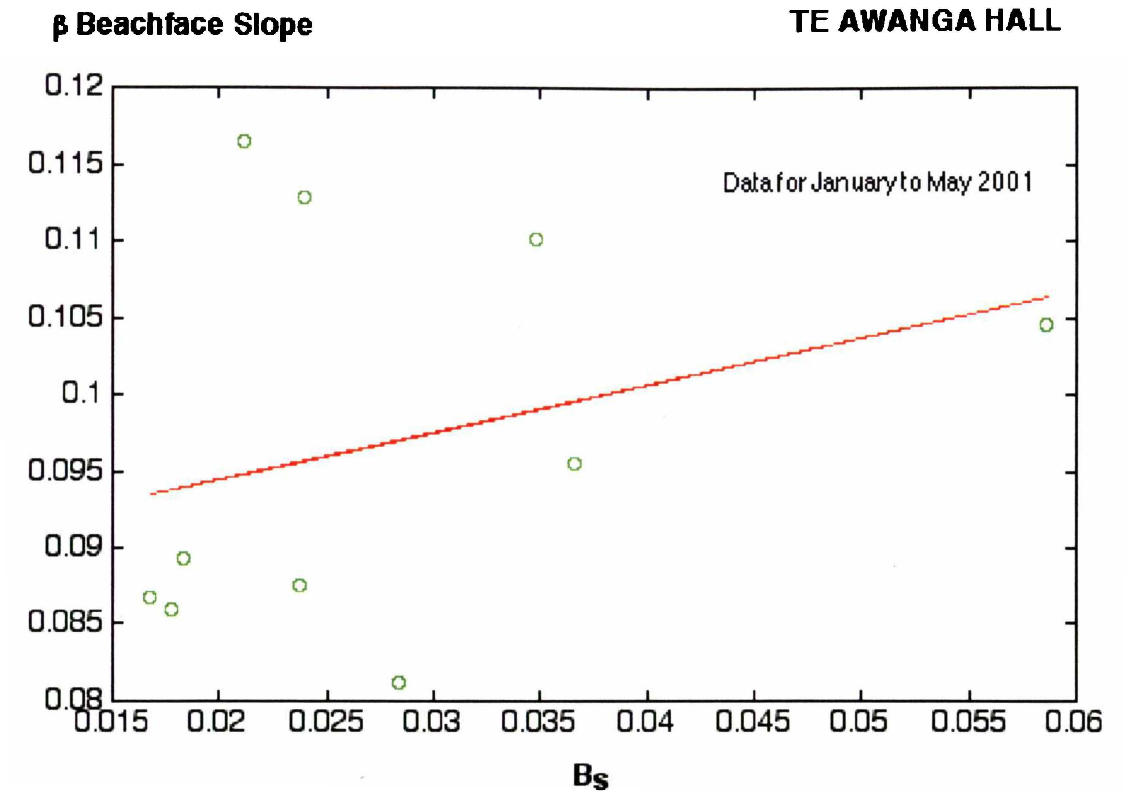


Figure 7.12 Te Awanga Hall. Iribarren number (ξ). Bivariate plot of beachface morphodynamics, beachface slope (β) and the breaking wave steepness (B_s). The linear regression (STATISTICA) for Te Awanga Hall R^2=9.26%.

Discussion, Bivariate Plots.

For the period January to May 2001, the change of sediment volume dQ and breaking wave steepness (B_s), Figure 7.9, suggests a well-defined boundary of wave type and morphodynamics. All sediment losses (erosion) occur for $B_s < 0.026$ (although at low B_s the sediment change can be accretional). Sediment accretion tends to occur when $B_s > 0.026$.

Figure 7.10, PI suggests the recurring beachface configuration is initially dissipative and becomes more reflective as B_s increases, and as the season shifts from summer (January) to winter (May).

Figure 7.11, surf scaling parameters of breaking wave and beachface slope, for HB show a clustering of dissipative (summer type) data, and an increasing scatter of reflective (winter type) beachface conditions.

Figure 7.12, Iribarren number morphodynamic parameter distributions are within the ORFORD (1977) field data for the MSG Llanrhystyd (Wales), but Te Awanga Hall has flatter, more dissipative beachface slopes. The Te Awanga Hall breaking wave type (from ORFORD, 1977; Figure 6 and Figure 9) suggests, firstly, the surging breakers (low value B_s), or summer profiles are erosive, especially when the beach slope (β) < 0.1, but when (β) > 0.1 the wave type becomes a collapsing type. This may explain why some low B_s associate with +ve dQ, Figure 7.9. Secondly, the plunger-spiller (high value $B_s > 0.026$) breakers are depositional. There is also some agreement with ORFORD (1977) who suggested storm beach sedimentation could be a process of spilling wave types because the outlier at $B_s = 0.056$, (Figure 7.12) is within the spilling type wave, however field observation at Te Awanga Hall have demonstrated surging waves can associate with steeper beachfaces and crestal overwash sedimentation.

Reflective beaches in South-Eastern Australia are embayed and semi protected (by headlands) environments and have coarse sediments hence low value surf scaling parameter (ε) (WRIGHT, et al., 1979). These SE Australian reflective beaches have linear beachfaces, developed berms (similar to HW ridges in HB) and beach cusps. Breaking waves measured up to 2.5 m to 3.0 m are surgers with high run-up and minimum set-up (WRIGHT, et al., 1979). The embayed reflective Braken Beach had (β) of 0.12 to 0.14 and (ε) 1.15 and 1.6, and Te Awanga can be within these ranges when H_b = 0.2 m. For both dissipative and reflective beaches, New South Wales, Australia, WRIGHT, et al. (1979) found accretion takes place when the surf scaling parameter, ε decreases, and conversely beaches erode when ε increases. The Te Awanga Hall site has the opposite morphodynamics where Te Awanga accretes at greater values of ε. This 'anomaly' is explored in the following Sections below.

On the eastern Canadian coast MSG beaches can have depositional sand aprons or cobble-boulder frames thought to accumulate by combined feed back characterised by erosional and depositional processes that act in similar ways at the beachface system (FORBES, et al., 1995). One-way the system acts is to shift from dominantly reflective to dissipative-reflective about ε = 2.5 and ultimately become dissipative (FORBES, et al., 1995). FORBES, et al. (1995) suggest combined dissipative-reflective systems are quite common. The eastern Canadian coastal surf scaling parameter may range 10^{-1} to 10^{3} as beachface slope changes from < 0.01 to > 0.5 over a tide cycle.

Regarding the beachface slope parameter, PONTEE (1995) suggests most eroding beaches in the UK are steeper than non-eroding beaches (measured as the landward recession of LW relative to HW). KIRK (1969) found eroding beaches to be flatter (dissipative) with the migration of the HW crest to landward, which may suggest the migration of the coast is perhaps faster in New Zealand.

Te Awanga Hall is a type 1 beach with Iribarren numbers between 1.6 and 4.0 (JENNINGS and SHULMEISTER, 2002). Type 1 beaches have small width, surging to collapsing waves, down combing of coarse sediments and up beach migration of a post storm ridge.

Results, Time Series.

The time series are: -

1). The sediment volume change (dQ), (ii) the profile index (PI) and (iii) wave steepness (B_s), Figure 7.13.
2). The surf scaling parameter (Figure 7.14), and
3). The Iribarren number (Figure 7.15).

Discussion, Time Series.

Over the period January to May 2001 the trends of the parameters at sampling intervals are the set showing (dQ), (PI) and ($B_{s)}$ (Figure 7.13); the surf scaling parameter (ε) (Figure 7.14) and the Iribarren number (ξ) (Figure 7.15).

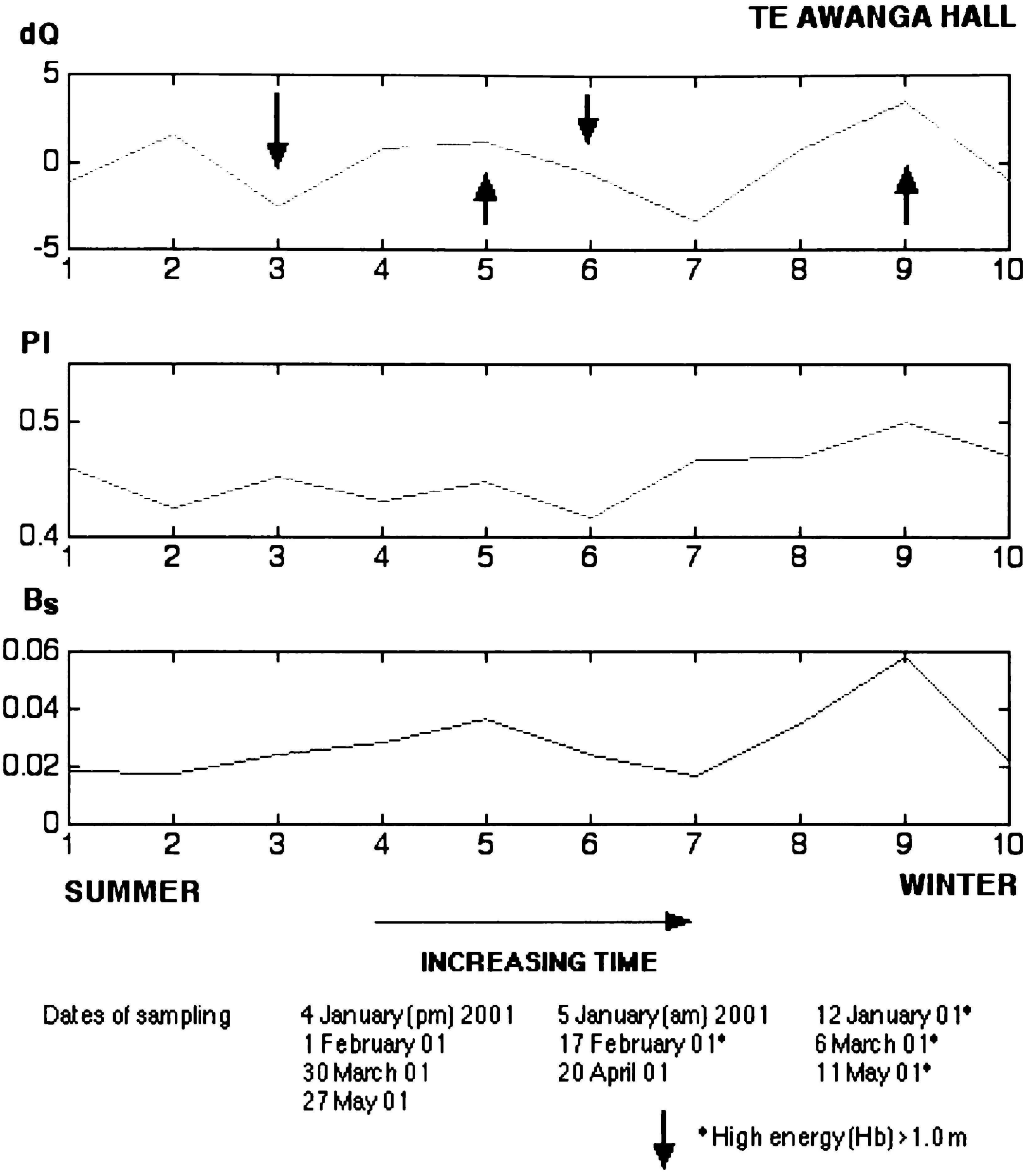


Figure 7.13 Te Awanga Hall. Temporal relationships of inter survey change of sediment volume m^3 (dQ); the profile shape index (PI) and wave steepness (B_s). Summer to Winter 2001.

Time Series dQ, PI and B_s at Te Awanga Hall.

Figure 7.13 has two main trends, the sampling period trend and the intersample interval trend.

1). The sampling period trends. All three parameters increase from summer to winter. The wave steepness (B_s) values increases from a summer of some 0.02, to a winter 0.04; PI increases from a dissipative (0.43) towards a linear (0.47) beachface, and the dQ becomes increasingly more +ve (from about -1.0 m^3 to +1.0 m$^{3)}$.

2). The intersample interval trends. The three parameters dQ, PI and B_s can show similar or dissimilar trends over equal time intervals. These trends are usually either accretional or erosional. For example, similar intersample trends occur at time intervals when all three parameters change in the same direction, viz. (T = time interval number on the Figure 7.13 'x axis') T = 4 to 5 and T = 7 to 9. At both of these intervals B_s increases (> 0.026), the PI changes from dissipative to linear, and the sediment dQ is +ve (accretional).

Dissimilar intersample trends can occur, for example (Figure 7.13) time intervals T = 2 to 3. Over this intersample period the wave steepness (B_s) increases, the PI increases and changes from dissipative towards linear, but the sediment dQ is -ve (erosional). This latter example coincides with a large wave event.

Note the first two parameters are of a 'daily' time scale whereas the remaining parameters are at 'monthly' intervals. What is of interest is the 'daily' scale of change can be as great as the monthly scale. This is to be expected. For example, the storm event over a single day can induce large-scale changes of the beachface sediment volume as measured in Chapters 10 and 11 for 'erosive' and depositional events.

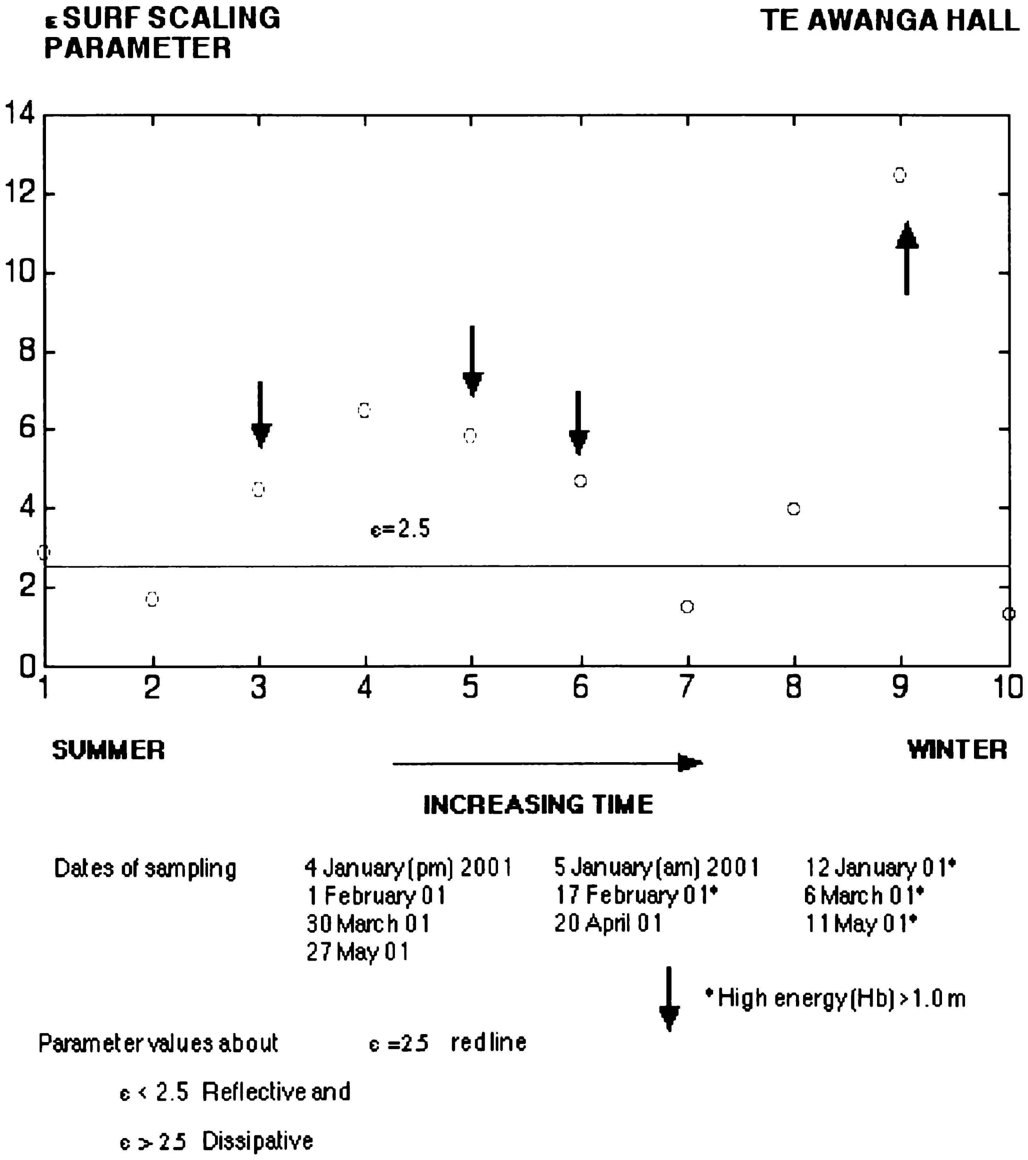


Figure 7.14 Te Awanga Hall. Temporal relationships of the surf scaling parameter (ε). Summer to Winter 2001. NOTE when $\varepsilon < 2.5$ a beachface is reflective and when $\varepsilon > 30$ it is dissipative as reported by WRIGHT et al. (1985), but Hawke Bay has a narrower range of values and the reflective-dissipative demarcation is narrowed to about $\varepsilon \approx 2.5$.

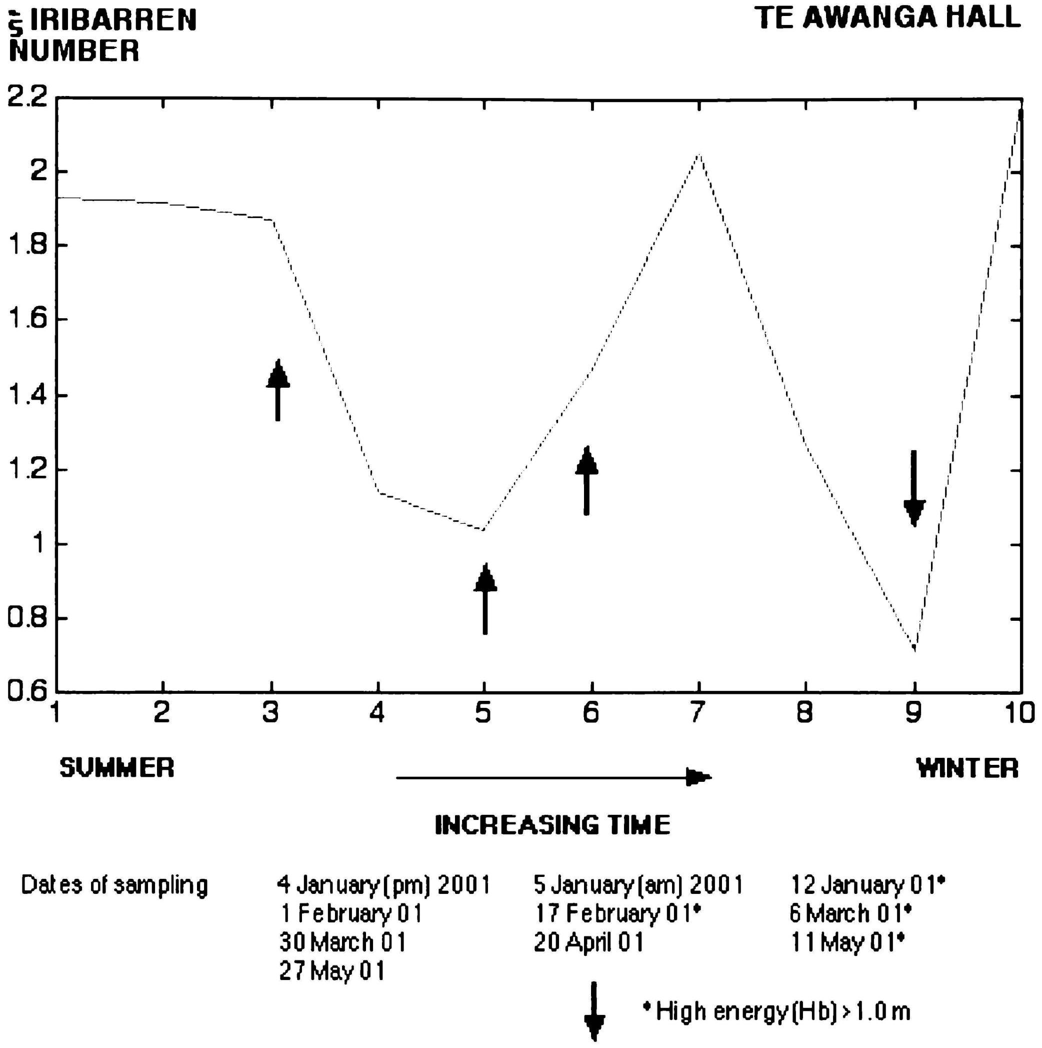


Figure 7.15 Te Awanga Hall. The temporal Iribarren number (ξ). Summer to Winter 2001.

Both the accretional and the erosional events associate with a reducing high wave (H_b > 1.5 m), although events are of different duration (January short; February long). The morphodynamics of both events have similarities and dissimilarities. See Appendix 12. The similarities of the morphodynamics are:

1). The previous high seas deposited sediments as overwash at the beach crest, on 12 January at 30 m cross-shore distance, and on 17 February at 21 m.

2). The platform and step erosion. It is possible sediments from the platform and step were selectively transported up the beachface. There is possibly selective sediment transport in the opposite cross-shore direction towards the nearshore.

3). Both the accretional and erosional events have morphodynamic changes about a position some +0.5 m above MSL. At this 'MSL', locus position there appears to be no sediment loss or gain (no change in either the vertical height or the cross-shore distance), hence this position could be a zone of persistent self-organisation.

4). The MSL persistent zone acts like a hinge, or locus, about which the beachface rotates. In response to high seas, the HW ridge gains vertical height and the platform decreases in height. This also steepens the beachface so that it becomes more reflective.

The morphodynamic dissimilarities (Appendix 12) are: -

1). Erosional events have characteristic erosion of the HW ridge whilst the accretional event has deposition at the HW ridge. This maximum change at the HW ridge site could be akin to antipersistent self-organisation.

2). The erosional event has a thin fill accretion at the swash run-up zenith limit whereas the accretional event has a thicker wedge of deposition.

3). Material from the eroded HW ridge can accrete at the platform. This accretion suggests the platform acts as a reservoir of sediment to be transported to the HW ridge during 'suitable' seas.

Time Series of the Surf Scaling Parameter.

The surf scaling parameter plot (Figure 7.14) shows a line that curves very smoothly between more dissipative and reflective about a value $\varepsilon = 2.5$. The most reflective values at T = 2 (5 January), and T = 7 (30 March) coincide with the lowest H_b ($H_b = 0.2$ m), and conversely the greater surf scaling values (dissipative waves) coincide with larger breaking waves (for example on Figure 7.14, T = 2 (1 February) $H_b = 0.8$ m and when T = 9 (11 May) $H_b = 2.0$ m).

In Figure 7.13 the peak +ve dQ (time interval T = 9; 11 May 2001) occurs coincidentally with peak ε (approximately $\varepsilon = 12$). This suggests the surf scaling parameter associated with sediment accumulation (+ve) dQ is $\varepsilon > 5$. For example at time intervals T = 4 and 5 (1 February and 17 February 2001) +ve dQ associates with a more dissipative wave break. However, there is also an instance of sediment accumulation with a small and reflective surf scaling parameter at T = 2 (5 January 2001).

WRIGHT, et al. (1979) found beaches accrete with decreasing values of ε "extreme cases where shoals climb onto the subaerial beach ε is rapidly lowered and the beach becomes fully reflective" (where ε is the inshore value between the HW ridge and the wave breaker bar or step). This is for sand textural sizes. As an extension, it could be that gravelly beaches require greater values of ε especially if inshore gravels are to be transported over the subaqueous step and to he HW ridge.

Time Series of the Iribarren number.

Figure 7.15 shows the Iribarren parameter oscillates between minimum values (ξ) < 0.8 coincident with greater B_s, a more linear beachface and +ve dQ, and a maximum (ξ) > 1.8, coincident with low B_s (approaching 0.02) and maximum -ve dQ (time intervals 7 and 10; 30 March 2001 and 27 May 2001).

From (BATTJES, 1974)

$\xi > 2.0$ collapsing;

$0.4 < \xi < 2.0$ plunger;

$\xi < 0.4$ spiller.

Generally, (Figure 7.15) values of ξ are in the plunger breaker type classification, although erosive wave breakers can be collapsing wave types (for example time intervals T= 7 and T= 10; 30 March 2001 and 27 May 2001).

Note, that in HB the ξ could decrease with higher seas, so that the wave type becomes more the spiller wave type, similar to that proposed by ORFORD (1977) for storm beach sedimentation. Although as observed and measured for Te Awanga Hall, (Chapter 5, Figure 5.9) the 'depositional' wave breakers differ alongshore and are often surgers.

MASSELINK, et al. (1999) note the morphodynamic behavior of a cuspate morphology about a value of $\xi = 1.2$, where cusp destruction takes place (erosion) at $\xi < 1.2$ and cusp formation (deposition) at $\xi > 1.2$. The Te Awanga Hall beachface shows the exact opposite where sediment dQ is generally +ve when $\xi < 1.2$ (Figures 7.13 and 7.15). Viewing the Te Awanga Hall parameters (Figure 7.15) when ξ <1.2 (time intervals T = 4 to 5 (17 February to 6 March 2001), and intervals T = 8 to 9 (20 April to 11 May 2001)) the wave steepness (B_s) increases above the critical 0.026, and the beachface becomes more linear (reflective) and the sediment dQ +ve (Figure 7.13).

BATTJES (1974) also suggests that beaches with a slope of some 0.01 and Iribarren numbers of 1 to 5 (Te Awanga Hall range) beaches are run-up predominant and reflective.

7.8 Conclusions.

Isopleths.

1). The beach crest and MSL isopleths may demonstrate a possible long trend cycle of some 33 months at Clifton.

2). Morphodynamic zones have either temporally persistent or as antipersistent zones of "self-organised criticality" (SOUTHGATE and MÖLLER, 2000). SOUTHGATE and MÖLLER (2000) place these zones in the marine inshore. In HB, these zones are located across the subaerial active beachface.

Geometric profile indicators.

The beachface geometric profile indicators are the parameters beach crest height (Hc); beach width (S), and the contained area (volume) (Q). From these three morphodynamic parameters the profile shape indicator (PI) is derived. PI can define a beachface as concave up (dissipative), linear, or convex up (reflective). Also considered is the parameter dQ (inter survey transverse profile volume change).

None of the morphodynamic beachface transverse profile parameters had a Gaussian frequency distribution. Generally, the parameters are skewed and/or have outliers (see Appendix 9). Some parameters can have a greater change at a particular sample site when compared to other sample sites. For example, at Haumoana the greater change of S relates to the accumulation of MSG sediments on the updrift side of a groyne construction that acted as a sediment trap over the early stages of the transverse profiling (WHITE and HEALY, 2000).

The two profile indicators dQ and PI can assist in classifying active beachfaces. For the HB barrier the parameter distribution ranges into Low, Medium or High. For example, a High dQ range and Low PI range beach is Marine Parade. The profile shape parameter (PI) shows the beaches have a range of profile shapes from linear to dissipative (concave up). These transverse profile indicators were arranged as bivariate plots and as time series. The bivariate plots of dQ: PI (linear least squares polynomial; regression) reveals two types of beach. Firstly as beaches depart from concave up to linear they can either become increasingly accretional (+ve dQ), for example Marine Parade, or increasingly erosive (-ve dQ), for example Te Awanga K2. Note that Te Awanga K2 has a 'seawall' that may have some bearing on the beachface morphodynamics. The regression gradient can be steep or flat, suggesting that as the profile changes towards linear from dissipative (concave up) the rate of sediment accretion or erosion will be greater at some localities than others. For example, Marine Parade has a steep gradient and Clifton a flat gradient.

Seasonal data selection from the Te Awanga Hall site shows that the bivariate relationships associated with $B_s < 0.026$ can be either – dQ or +ve dQ. However, at $B_s < 0.026$ the -ve dQ relates (under the Chapter 12 classification, ORFORD, 1977) more with surger wave types on a dissipative beachface, whilst the +ve dQ associates more with collapsing type breakers. However, from Chapter 5 it is observed that the accretional breaking wave types are surgers and foaming plungers. Generally for the Te Awanga sampling site over the autumn 2001 the +ve dQ corresponds with $B_s > 0.03$. Te Awanga Hall had a maximum +ve dQ with $B_s = 0.057$.

The PI values appear constrained suggesting small morphodynamic changes take place over a wide range of wave steepness.

Time series trends (linear least squares polynomial gradient; linear regression) over the sampling period (May 1998 to June 2002) show most beaches (rank order Haumoana > Te Awanga Hall > Clifton > Te Awanga K2) have a -ve dQ/dt suggesting long time sediment erosion (barrier beachface sediment depletion). Marine Parade has a very slight +ve dQ/dt (accretion). Indeed Marine Parade has an almost flat gradient of both dQ/dt and PI/dt. Most beaches (rank order Haumoana > Clifton > Te Awanga K2) have a +ve PI/dt, or the beachface PI is evolving from a concave to a linear profile and becoming more reflective. The -ve PI/dt, or increasingly dissipative beachfaces (evolving from linear to concave) are in rank order Te Awanga Hall > Marine Parade.

These results suggest that as beachfaces profile evolves from dissipative to linear (more reflective) the sediment loss increases, for example Haumoana and especially Te Awanga K2. Both Haumoana and Te Awanga K2 have associated 'defenses' with K2 a 'rail iron and tyre seawall' and Haumoana a concrete tetrapod groyne.

The time series morphodynamics measured as the profile indicators (dQ; PI; β) and the incident breaking wave steepness (B_s) investigate the relationships of the surf scaling parameter (ε) and the Iribarren number (ξ) as a season (January to May 2001, a summer to winter season) for the Te Awanga Hall beachface. The surf scaling parameter was generally of low value and fell below the 'critical' $\varepsilon = 2.5$ that can delineate between reflective $\varepsilon < 2.5$ or dissipative $\varepsilon > 2.5$ beaches. For example field data (NSW, Australia; WRIGHT, et al., 1979) suggests sediment accretion takes place as ε decreases, but the Te Awanga Hall site can be contrary with maximum dQ associated with the greater ε, and, a profile index (PI) changing from dissipative (concave up) to more linear.

Also at Te Awanga Hall the Iribarren number (ξ) ranged from 0.6 to 2.2. The minimum (ξ) < 0.8 is coincident with greater B_s, a more linear beachface and +ve dQ. Over the same season the maximum (ξ) > 1.8, coincided with low B_s (0.02) and maximum -ve dQ.

On comparing the two time series trends, firstly the sampling period June 1998 to May 2001 'evolution' trend and secondly the seasonal (January to May 2001) trend. The indications are that the Te Awanga Hall beachface evolution is for -ve dQ with -ve PI; whereas, the seasonal trend is for +ve dQ and +ve PI with an increasing B_s. This suggests that the Te Awanga Hall beachface is accretional going into a winter with a net late summer accretion period.

General conclusions.

PI changes have known causes for example two ‘constructions’ took place over the sampling period, at Haumoana a groyne, and at Te Awanga K2 a ‘seawall’. These constructions represent cross-shore (seawall) and longshore (groyne) impacts.

A detrended time series (Clifton) can indicate characteristic HB morphodynamics responses classified as (1) non-rotational or (2) rotational.

1). The non-rotational morphodynamics have characteristic accretion at the HW ridge and some time later further material deposits and ‘welds' onto the established antecedent HW ridge. For these events, the topographic adjustments across the swash zone are small and near beachface slope parallel.

2). Rotational morphodynamics have characteristic accretion or erosion at the HW ridge accompanied by opposite topographic adjustments at the lower beachface platform. For example, the accretion event at the HW ridge is accompanied by erosion at the platform, conversely with erosion of the HW ridge there is accretion at the platform. The MSL zone acts as a hinge (locus) with small topographic change about which the beachface rotates. Hence, the MSL zone is a persistent zone and the HW ridge an antipersistent zone.

Note that -ve dQ/dt has associated errors. For example, at the sample sites if gravels transport to landwards as overwash sediments during a storm event they would ‘in the real world’ pass into storage. There are several examples of this. For example at the ‘tyre’ seawall at K2 in Te Awanga, the gravels can be prevented from passing too landward. In HB, the local government removes these storage sediments to 'tidy up' recently deemed car parks and recreational areas. Therefore, sediments cannot pass into storage. These human responses generate causal inherent error in modeling the coastal system. Overwash sediments are not included in budget models and consequent erosional losses are inaccurate. Further, the landward limits of coastal flooding are also made difficult to measure since the flotsam is ‘tidied up’ before measurements can be made.

CHAPTER 8 THE SEDIMENTARY CHARACTERISTICS OF MIXED SAND AND GRAVEL BEACHFACES.

8.1 Introduction.

This chapter reviews the literature on the gravely beach textural sizes and forms (and select sand beach textural sizes) in the cross-shore and alongshore directions, including river supply, and reflective beaches that are applicable to the Hawke Bay barrier beachface, to formulate qualitative models. The data analysis for the southern Hawke Bay gravel beach textures is presented in Chapters 9 to 11, and 13 and 14.

8.2. Clast Textural Analysis.

The sediment size description used in this study follows the mm (Phi) Wentworth scale, with gravel sizes defined as intermediate diameter I = > 2 mm (-1.0 Phi), (ANDREWS, 1982). The Phi scale is defined as: -

$$\phi = \log_{-2}(d_{50}) \qquad (1)$$

where

$d_{(50)} =$ intermediate axis length (mm)

whereas, 'size' is a one-dimensional measure of a clast, the intermediate axis length, (mm), the clast form is a three dimensional measure of the orthogonal axis representing the long, intermediate and short axis lengths (mm). The forms identyfied in this research utilise the ZINGG classification with classes of blades, discs, rods and spheres (ZINGG, 1935, cited in BLUCK, 1967). In addition, the oblate prolate index (OPI) from (DOBKINS and FOLK, 1970) and maximum projection sphericity (MPS) from SNEED and FOLK (1958) are used. The parameter derivations are located in Appendix 4 along with the clast size classes and sampling methods. The following Sections review sediment patterns associated with (1) cross-shore, (2) longshore, (3) reflective beaches, (4) and sediment supply effects.

8.3 Sediment Textural Patterns.

Cross-shore Size-sorting.

The southern HB beachface generally has well-defined surficial sediment patterns as distinctive zones, similar to those reported for the South Island east coast MSG barriers KIRK (1980). KIRK (1980) reports surficial cross-shore sediment textural zones of very fine sands inshore, coarse cobbles off the step, MSG on the beachface, and a coarse gravel berm, or storm ridge on the upper beachface, and backbeach. The beach crest attains the greatest elevations where the sediments are the coarsest, for example in the South Island east coast (KIRK, 1980), and for Chesil Beach in southern England (KING, 1959).

Contemporary MSG barrier beaches have coarse backbeach gravels (KING, 1959; BLUCK, 1967; CARR, 1969) while offshore are typically sands (KIRK, 1980). Similar sediment textures occur in the geological stratigraphic column with rippled sands and interbedded gravel apparently representing high-energy environments (BOURGEOIS and LEITHOLD, 1984; LECKIE, 1988).

McCLEAN and KIRK (1969) explored the relationship between the sediment size and beachface slope and found the larger the grain size the steeper the beachface slope, now a well recognised relationship. For the South Island gravels when plotting the bivariate relationship between grain size (Phi) and beachface slope, the linear least squares best fit has a gradient of low angle and this appears to hold true for both pure gravel and MSG-composite beaches all around the South Island (JENNINGS and SHULMEISTER, 2002). KIRK (1980) concluded that this low gradient might be because the beaches were erosional. However, it remains that in the South Island there appears to be a relatively small range of gravel sizes for a wide range of beachface slopes.

In the South Island, both sediment size and sorting can influence the beachface morphology. The better sorted sediments tend to have steeper beachfaces, and poorly sorted sediments have lower slope beachfaces (KIRK, 1980).

MOUTZOURIS (1991) found for tide less Greek MSG beaches "grains" are coarser and "worse sorted" on high energy beaches, and finer grained and better sorted on low energy beaches. At the step the material is the coarsest and worst sorted, especially at the step toe. From the step the textural grain sizes decrease landward.

Gravel pattern development is primarily a sorting process. However, two broad schools of thought are apparent, identified as the clast transport, and the clast lag schools. KING (1959) and BLUCK (1967) suggest storms selectively sort and transport material where coarse, mostly discoidal form clasts, are lifted and deposited above high water. SHULMEISTER and KIRK (1997) suggest that in the South Island the HW ridge gravels accumulate in a storm when the sands selectively winnow leaving a lag of coarse gravels. This suggests the South Island example beachface has a small sediment supply.

There are also identifiable differences reported between gravel populations at the high water and low water. Using the clast long axis CARR (1969) found Chesil Beach gravel at the low water mark to be bimodal, and those on the upper beachface (high water mark) to be unimodal, and by implication the unimodal gravels should have better sorting.

The cross beachface sediment sorting process is a product of swash/backwash phase difference (KEMP, 1975) above the low water level (CARR, 1971; KIRK, 1980). This phase difference is associated with the incident wave fetch, for example, the maximum wave fetch at Chesil Beach is at the eastern beachface where the coarsest gravels occur.

Alongshore Size-sorting.

For the coarse beach crest at Chesil Beach the sizes grade alongshore. This grading is also in the direction of the dominant wave fetch, from west to east, so that the smallest clasts are found in the west and grade to the largest clasts at the eastern extremity near Portland Bill (KING, 1959; CARR, 1969).

Not all longshore sediment patterns are so distinctive. Longshore trends of mean grain size and/or sorting take place on either pure sand (McCAVE, 1978) or gravel beaches (CARR, 1971) but for the South Island MSG beaches, the relationships are less distinctive (KIRK, 1980). CARR (1971) demonstrated that tracer clasts differentially disperse so that the large clasts transport towards the eastern Chesil Beach. Conversely, there is no clear picture of linear or cyclic variations of sediment size sorting in the longshore direction of the South Island, east coast (KIRK, 1980).

For reflective beaches in New South Wales, BRYANT (1982) noted a temporal stability of the longshore grain size grades "which may show as little as 5% variation at any one location on the beach". BRYANT (1982) suggests the process for these longshore sediment patterns is a product of incident wave energy gradient, However, the wave energy does not explain the coarse grain gradients, and that the wave energy only affects the rate of change. BRYANT (1982) suggests that the incident wave refraction remains consistent on particular beachface morphologies, so that reflective beaches invariably receive shore normal waves and dissipative beaches shore oblique waves.

In this study the McLAREN (McLAREN and BOWLES, 1985) model is applied to the gravel sizes, but it appears this model has only been applied to the sand sizes. For example, MASSELINK (1992) demonstrated that the known longshore sediment transport direction and the McLAREN and BOWLES (1985) model that could explain the geographic sediment parameter dispersion pattern, do not agree. For the sand beach along the Rhone delta, southern France, the known transport direction is to the west. Sediment textural analysis shows that the sediment pattern becomes finer, and the sorting becomes more poorly sorted towards the west. The model (McLAREN and BOWLES, 1985) suggests sediments in a transport direction should become either: -

1). Finer, better sorted and more negatively skewed, or

2). Coarser, better sorted and more positively skewed.

MASSELINK (1992) suggests that reasons for this divergence from the model could include non unidirectional transport flow (longshore transport is frequently bidirectional); sediments can be from more than one supply, and sediment transport can be strongly influenced by wave energy level (BRYANT, 1982) and the beach stage (erosional or accretional).

Studies of the temporal grain size parameter relationships suggest the parameter changes are not uncommon over various temporal scales. For example ranging from (1) long term (annual) (GUILLÉN and PALANQUES, 1996; McKAY and TERICH, 1992), (2) short term (monthly) involving wave energy (BRYANT, 1982) and (3) related to the morphodynamics of accretion, or erosion (SONU, 1972). For longer time scales, McLAREN and BOWLES (1985) present a sediment transport model where (1). As the original sediments (supply sediments) rework by the incident energy, and as reworking continues, or as energy increases the sediments become finer and more negatively (-ve) skewed, and (2). As the energy decreases the sediments become coarser and more positively skewed (+ve).

These McLAREN and BOWLES sediment size changes occur along the direction of transport, for example downstream river, or alongshore, but they may also be applicable to a sample site over time. GUILLÉN and PALANQUES (1996) suggest "if the seasonal wave climate were the single controlling factor of temporal grain size evolution, the beach sediment would show a steady grain size trend over time." GUILLÉN and PALANQUES (1996) suggest the variations of the grain size trend relate to the sediment supply where increasing sediment supply results in net deposition and a decrease of the supply results in net erosion. The eroded sediments tend to be finer and transport to accretional areas. Hence accretional areas have a trend of fining sediment and the erosional areas have trends of coarsening sediment, (McLAREN, 1981, cited GUILLÉN and PALANQUES (1996)) and these processes may have a temporal dimension different from the seasonal wave climate change related grain size distribution pattern, for example GUILLÉN and PALANQUES (1996) demonstrate for the erosional Ebro delta (Catalan coast, NW Spain) trends of coarsening, better sorting and less negative skewness between 1988 and 1991.

BRYANT (1982) relates wave power to the cross-shore (and alongshore) size parameters for both dissipative and reflective beaches in an embayment (NSW, Australia). BRYANT (1982) suggests that as wave power increases so the mean grain size increases (become coarser) and the sorting coefficient increases (sediments become more poorly sorted). However, this also implies the unlimited availability of sediment with limited sediment availability the coarse sediments move faster and have early deposition downdrift (and the fines have late deposition) where this is a possible explanation of the longshore variation.

Cross-shore Clast Form.

Across the beach, clast forms vary with a lower beachface dominated by spheres, and an upper beachface by discs. This cross beach form differentiation was first proposed experimentally by LANDON (1930) who suggested the discs shift by wave action and shift to the beachface whilst the spheres move to a swash zenith but can roll faster and further in the backwash and tend to deep water where they rapidly bury.

Clast form pattern differences are evident on MSG beaches, both with (CALDWELL and WILLIAMS, 1988; SHERMAN, et al., 1993) and without (BLUCK, 1967) a cuspate morphology. Field sites on the south coast of Wales typified the cross-beach gravel organisation with Sker point and Cwm Nash as storm beaches with a high-energy winter type beach ridge, and Newton Beach as the low energy summer type beach (BLUCK, 1967). BLUCK (1967) suggested gravel bars (ridges) build up on the beachface during storm conditions since gravel boulders are found on or above the high water mark. BLUCK (1967) also notes that in storms all gravel sizes transport landward, whereas in normal conditions transport is confined to high water mark large (disc form) pebbles.

The high energy Sker Beach, Wales cross-shore size (intermediate axis length) pattern changes were (BLUCK, 1967): -

Gravel Zone	Beachface Location	
large gravel size (discs)	beach crest,	
an imbricated zone comprising a wide range of sizes	high water ?	
sand sheet and (spherical and rod form) gravels	high water	infill zone start
narrow band (spherical and rod)		
cobbles infilling with pebbles (spherical and rods)	-MSL ?	infill zone finish
cobbles (spherical)	outer frame	
sand	low water ?	

Beachface gravel samples at the onset of a storm represent the original or parent population, with a coarse ‘frame’ near the high tide mark, infilled with granules and sand. To seaward of high tide, the sediments represent the gravel reworking and are the “worst sorted seen on the beach” (BLUCK, 1967).

CALDWELL and WILLIAMS (1988) also examined the high energy Nash Beach, and a low energy Gileston Beach, both in Wales, using clast size and form data. Results for the Gileston beach clast form, arranged cross-shore are: -

Gravel Zone	Beachface location	
large (discs)	beach crest	
discs	imbricate zone	high water?
discs (+rods, discs and spheres)	infill	
discs? (+rods and spheres)	infill	
discs? (+rods and spheres)	beach toe (BLUCK's outer frame?)	low water?
blades	shore platform	

These patterns are defined by non-parametric (KOLMOGOROV-SMIRNOV) statistical testing. Cross-shore zonation of the low energy Gileston Beach has a greater definition (parameter tests proving significant at $p \leq 0.01$) than Nash beach.

SHERMAN, et al. (1993) sampled surficial sediments across the 300 m long Portmore Beach, northern Ireland. This beach has a steep beachface and the wave is high energy, refracted, with a surf scaling parameter $\varepsilon < 2.5$, reflective with a developed edge wave thought to be "the primary agents of beach cusp formation". Samples collected on a waning storm represent an accretionary phase typified by an up-beach migration of the clasts, and therefore represent a sediment facies-morphodynamic typology. Principal component analysis shows distinctive facies, (clast sizes) and MPS (maximum projection sphericity - SNEED and FOLK, 1958), for the defined upper and lower beachface cuspate morphology. This is a similar finding to DOBKINS and FOLK (1970) for the contemporary Tahitian beaches. SHERMAN, et al. (1993) describe cusp horn clasts across the upper and lower beach. Generally, the gravels become coarser up the beachface. The lower beachface horn top clasts had a greater MPS, tending to more spherical from rod forms, and were angular and large.

Alongshore Clast Forms, (Source, River and Alongshore Clast Forms).

BLUCK (1967); ORFORD (1975) and CALDWELL and WILLIAMS (1988) have demonstrated the organisation of gravels forms at open coast high-energy beaches, and (NORDSTROM and JACKSON (1993) at more sandy, sheltered beaches. However, these experiments are usually for small longshore lengths, can be short duration and can take into account the morphogenesis. ORFORD (1975) demonstrated the possibility of seasonal clast forms by multivariate and cluster analysis

BLUCK (1967) found some suggestion of alongshore clast form segregation by a process of preferentially selection of clast forms, for example, spherical and rod form clasts tend to move faster and may have a lower threshold of transport (BLUCK, 1967). BLUCK (1967) cites field experiments where painted spherical and rod tracers transport seaward in the backwash. Gravel transport increases as saltation increases and the saltating population increases towards the equidimensional, compact (spherical) forms (ISLA and BUJALESKY, 1993). The broken wave swash induces a process of form selection best demonstrated near low tide.

KEMP (1975) has theoretically shown and demonstrated the swash and backwash water velocities need not be identical. Usually the swash water velocities are greater than the backwash velocities. The percolation of water into the beachface sediment fabric induces the water velocity difference by reducing the return water flow across the beachface. If the sediment fabric is gravely with clast-clast contacts and without a sand matrix, the percolation is maximum. Maximum percolation reduces the beachface surface return flow volume and by extension reduces the backwash velocity.

Towards the beachface crest, (with gravels) the return flow is less than at the step (with grits and sands), where percolation waters can issue from the beachface, coupled with the breaking wave water volumes. There are also other instances when the return backwash volumes decrease, for example where this could be the beach crest overwashing.

Water velocity differences induce selective gravel form transport through a threshold of motion process. Assuming gravel size equivalence rapid swash flow transports discoidal forms towards the beach crest and the slower backwash velocity transports spheres. This cross-beach form selection coupled with the suggestion that large clasts selectively transport (KOMAR, 1986) and increase in frequency in the down drift, or littoral drift direction, for example Chesil Beach, England (CARR, 1969) and could account for the size and form sorting alongshore. These preferred clast transport processes suggest the clasts in the down drift direction in HB should become larger and more spherical.

Whilst discs at the beach crest can become isolate from 'normal' swash processes there is suggestion that these can change form. KUENEN (1964) reports experimental results where the most stable clast forms, discs, became increasingly more rounded and thickened as the disc edges reduce (becoming increasingly bladed and rod form, and increasingly prolate); indeed, clasts on the HB barrier can have observable edge abrasion.

These preferred clast transport processes suggest the clasts in the down drift direction in HB should become larger and more bladed, spherical and rodical, leaving a lag of coarse discs.

Studies of gravel clast changes over longer distances, 10's of km, appear to be few. Examples of clast modification over some distance by terrestrial (river or lake) transportation include the study of glaciogenic clasts (GREGORY and CULLINGFORD, 1974; BENN and BALLANTYNE, 1994). Methods of data analysis use a derivative of ZINGG (short axis/long axis) and a roundness index based upon defining a sample clast roundness by a class interval (for example classes ranging from very angular to rounded). Other studies have involved downstream changes of a clast (MILLS, 1979) and the importance of clast lithology in determining the eventual clast form. For example, DRAKE (1970) cites SMALLEY (1966), who predicted "the fracture of isotropic rocks in random directions should produce 11.1% spheres, 22.2% blades and 66.7% combined rods and discs".

DOBKINS and FOLK (1970) suggest that MPS differentiates between river and beach clasts no matter what the lithological composition of the clast. This MPS differentiation is: -

Beach < 0.66 < rivers. (MPS Limits 0 to 1).

DOBKINS and FOLK (1970) data are for short river course samples from V shape valleys near the Tahitian coast. Generally, the river clasts differ from coastal clasts by two main factors; (1) the average river clast roundness is the least compared to both low and high wave energy beach clasts, and (2) the river clasts have the greater MPS values.

DOBKINS and FOLK (1970) introduce the oblate prolate index (OPI) to differentiate between discs and rods, where (a) a perfect blade form has an OPI value of 0.0, (b) discs have increasing negative values and (c) rods increasing positive values. The OPI values for clast from the three transport environments are: -

Transport Environment	OPI	Ave OPI (all sizes)
Rivers	all +ve	+0.18 (prolate)
Low Energy Wave	all -ve except	-0.81 (oblate)
High Energy Wave	all -ve	-2.13 (oblate) for select size 128 mm - 256 mm

These values indicate that a clast moving from a river environment and onto a beach with increasing wave energy will have increasing disciness. Of the clast form indices, DOBKINS and FOLK (1970) suggest that the clast MPS is a better discriminator between river and beach environments especially on Tahiti as the rivers are too short to modify by transport the clast rounding, otherwise the clast would approach similar roundness in both fluvial and marine environments. MPS would increase with prolonged fluvial transport and decrease "with prolonged beach abrasion". MPS closely matches the clast settling (and traction) velocity and reflects clast behaviour such that clast "shape is affected strongly by wave height". DOBKINS and FOLK (1970) show the average Tahitian MPS for all river clast sizes averages 0.684; for low energy beaches is 0.640, and for high energy beaches 0.584 and generally MPS is least for clasts on sandy beaches. Of the MPS data scatter for all sizes, the beach pebbles have a smaller scatter (variation) than the contemporary river pebbles.

There are detectable sand-gravel content relationships as might be expected at a river inlet. These relationships for MPS are: -

	Maximum Projection Sphericity	
Beach Type	Small Pebbles	Large Pebbles
Pure gravel	0.68	0.53
MSG	0.54	0.56

This suggests that sandy inlets 'protect' clasts, as observed by BLUCK (1967) for the Newton Beach near the Ogmore River inlet, Wales.

BLUCK (1982) notes that for four river channels sampled the clast form segregation on river bars is not repeated for the river channels, including the Ogmore River that enters the coast at a beachface gravel study site BLUCK (1967). Clast form sorting (form segregation by unidirectional hydrodynamics) is effective for the courser sizes at bars where discs concentrate at the bar head and spheres at the down-stream tail. Along some 20 km of Ogmore River channel, the clast forms show a downstream decrease of discs and an increase of spheres. BLUCK (1982) notes that clast size and sorting are not well differentiated downstream for bulk samples, but the largest size clasts do show downstream trends, with a decrease in grain size and an increase of the sediment sorting.

Clast size and form 'selection' as clasts pass from a river to a marine environment can have a process that does not evoke time spent in transport or prolonged abrasion by sliding. Less than "1 mile" (1.6 km) from the coast the Ogmore River contains 80% sub-greywacke in all sizes (35 mm to 95 mm). The sub-greywacke is fissile and splits to produce discs so that there is correlation between clast lithology and form. At the coast there is a reduction of sub-greywacke sizes with increasing smaller sizes and increasing blades and discs. At Newton smaller gravel sizes of sub-greywacke are less mature (less frequent than other lithologies derived from backbeach glacial tills), possibly as a result of storm abrasion (breakage) of large clasts (BLUCK, 1967). Breakage of fluvial clasts entering the coastal environment is also observed for the MSG Bianco Beach, southern Italy (BARTHOLOMA, et al., 1998).

It may be instructive to view the MPS and OPI values in the cross-shore and longshore directions. In the cross-shore direction the clast form values found by DOBKINS and FOLK (1970) are: -

Cross Beach Site	MPS	OPI
Crest	Low MPS	More Oblate more -ve values
Low beachface (cusps)	High MPS	Less Oblate more +ve values

The low beachface cusp clasts described by DOBKINS and FOLK (1970) as "anti beach" may contain mostly rods since the bay sediments were described as sands with discs.

In the longshore direction away from a river inlet source, the clasts have a decreasing MPS (increasing disciness), and the OPI values indicate the clast has increasing flatness (increasingly oblate) (DOBKINS and FOLK, 1970). Longshore direction (8 km) clasts measured on Bianco Beach, southern Italy (BARTHOLOMA, et al., 1998) indicate MPS decreases for specific lithologies 0.05 (granite) to 0.06 (gneiss), overall the OPI has no change of "meaningful interpretation". Roundness (using KRUMBEIN (1941(b))) visual roundness comparator chart) increases in the direction of transport, again with lithological difference (granite 0.17; gneiss (0.12).

Sediment Textural Patterns on Reflective Beachfaces.

Comparing dissipative and reflective beachfaces in Broken Bay, Australia BRYANT (1982) describes the reflective Pearl Beach morphology as persistent in time with a steep beachface slope and a longshore cuspate morphology. Pearl Beach later became a field site to explore the beachface step morphodynamics (HUGHES and COWELL, 1987).

BRYANT (1982) tested the grain size relationship with reflective and dissipative beachface morphologies. This was in association with the hydrodynamics at select longshore sampling sites based upon two hypothesis firstly as the sediment settling velocity (size) increased it was expected that the sorting coefficient would increase as the shore normal wave power increased, and secondly alongshore decrease of sediment size accompanies an increase of sorting.

The sorting coefficient, by statistical moment measures is: -

$$\frac{\text{Sorting (or standard deviation)}}{\text{Mean grain size}} \qquad (2)$$

For the reflective Pearl Beach, BRYANT (1982) found in the alongshore direction towards the north the sediment settling velocity (size) increase accompanied an overall decrease of the sorting coefficient. This beach has an alongshore energy gradient ranging from a low energy southern beach to a high-energy northern beach. Whilst the sorting coefficient decreased, overall the alongshore spatial variation was both rapid and large. However, at any particular site the sorting coefficient remained stable in time (this included a major storm event). BRYANT (1982) considered the main processes depended on the sediment texture. For example, the downdrift increase of the coarse grain sizes is a product of coarse size grain exposure in a turbulent swash since the large sizes would protrude into the turbulent swash and is more susceptible to transport. BRYANT (1982) found that the sediment-sorting coefficient increased as cross-shore wave power increased at sites alongshore.

Sediment Supply Effects.

Supply areas may have a wide range of material sizes, because the supply can be variable, by both the rates of erosion and the availability of material sizes, for relatively high energy beaches (KIRK, 1980) and at low energy beaches. MOUTZOURIS (1991) has also found sorting can be worse in sediment supply areas.

8.4 Hawke Bay Clasts-Conceptual Models.

As a synthesis to the previous sections it is proposed to develop some conceptual models: -

1). Supply of gravels.
2). Size and form on reflective beach with an energy gradient alongshore,
3). Size and form relationships across the shore (beachface).

The Source and Supply of Gravel to the Contemporary Hawke Bay Coastal Environment.

The supply area effects for the HB gravels could include a highly variable clast size and form and a variable rate of supply from both the Cape Kidnappers colluvium, and the coarse bed load from the supply rivers (Maraetotora and Tukituki). At the coast the Cape Kidnappers gravels are quite different to those from the Tukituki. The Tukituki gravels tend to be none fissile and have no jointing whilst the Cape gravels have dilatation jointing, so that as the compressed solid cliff material releases by splitting away from the cliff face the contained gravels undergo compression release, hence the clasts can split along fairly well defined jointing planes that intersect at some 120 °, producing a range of clast forms centred on a triclinic form (three axis not at right angles to each other and of variable length that intersect at a centre of symmetry). Hence, clasts on average are more angular (brecciated) at Clifton that at the Marine Parade beach where clasts tend to be rounded, smooth skin and polished, especially the fine grained argillitic clasts.

The greywacke gravels associated with the HB barrier have a source, and supplies (Figure 8.1). Figure 8.1 shows the two main clast supplies, (i) fluvial, and (ii) coastal. The greywacke source is the Ruahine Ranges (Figure 8.2) that run coast parallel some 40 km inland. In geological time the greywacke gravels found at the Cape Kidnappers (Figure 8.3) came mainly from the Ranges (including other minor stratigraphic lithologies, for example the Early Castlecliffian Te Whaiti ignimbrites (BEU and GRANT-TAYLOR, 1975)) and since the later Holocene have supplied the HB barrier. The greywacke gravel supplies to the coast are primarily the contemporary rivers and the Cape Kidnappers cliffs (relict fluvial). Secondary supplies of the greywacke gravels include erosion of the sub-marine platform off Cape Kidnappers and cannibalism, or barrier reworking.

Hawke Bay is fortunate, firstly to have a similar greywacke material dominant in the recognisable supplies, and secondly, the peculiarities of the greywacke gravel at a particular supply mostly have attributes associated with fluvial transport processes. For example, KAMP (1975) has demonstrated the fluvial origin (except for the uppermost marine facies) of the Cape Kidnappers conglomerates. Therefore, the fluvial process gravels are present in both the geological and in the contemporary time scales. This leads to the concept of the stratigraphic gravels. Stratigraphic gravels are useful for two purposes.

1). Firstly these gravels can be measured at a spatial and a temporal equivalent scale both near the Ranges (Hawera Terrace) and at the Cape Kidnappers (Castlecliffian). This is neat since it enables the measurement of clast modification in both an ancient fluvial system and in the modern Tukituki River system.

2) Secondly, the stratigraphic gravels from near the Ranges are a basis to compare any changes to the gravel forms over the Pliocene to Recent geological time scale.

Because the supplies of the HB gravels are predominantly fluvial, there should be maximum change to the gravel clast forms as they move from a fluvial into a marine environment. DOBKINS and FOLK (1970) and BLUCK (1982) suggest expected modifications to clast forms as they cross from a fluvial to a marine environment. For example, at the coast DOBKINS and FOLK (1970) suggested three possible environment induced clast changes as: -

1). “Agnostics”-there is no systematic change in clast form either from rivers or from the coast.

2). “Sorters”-clast forms are used more than made, hence discs are thrown high onto a beachface, whilst the spherical clasts roll to the base of the beachface, and

3). “Abraders”- the surf process abrades the clasts into disc forms.

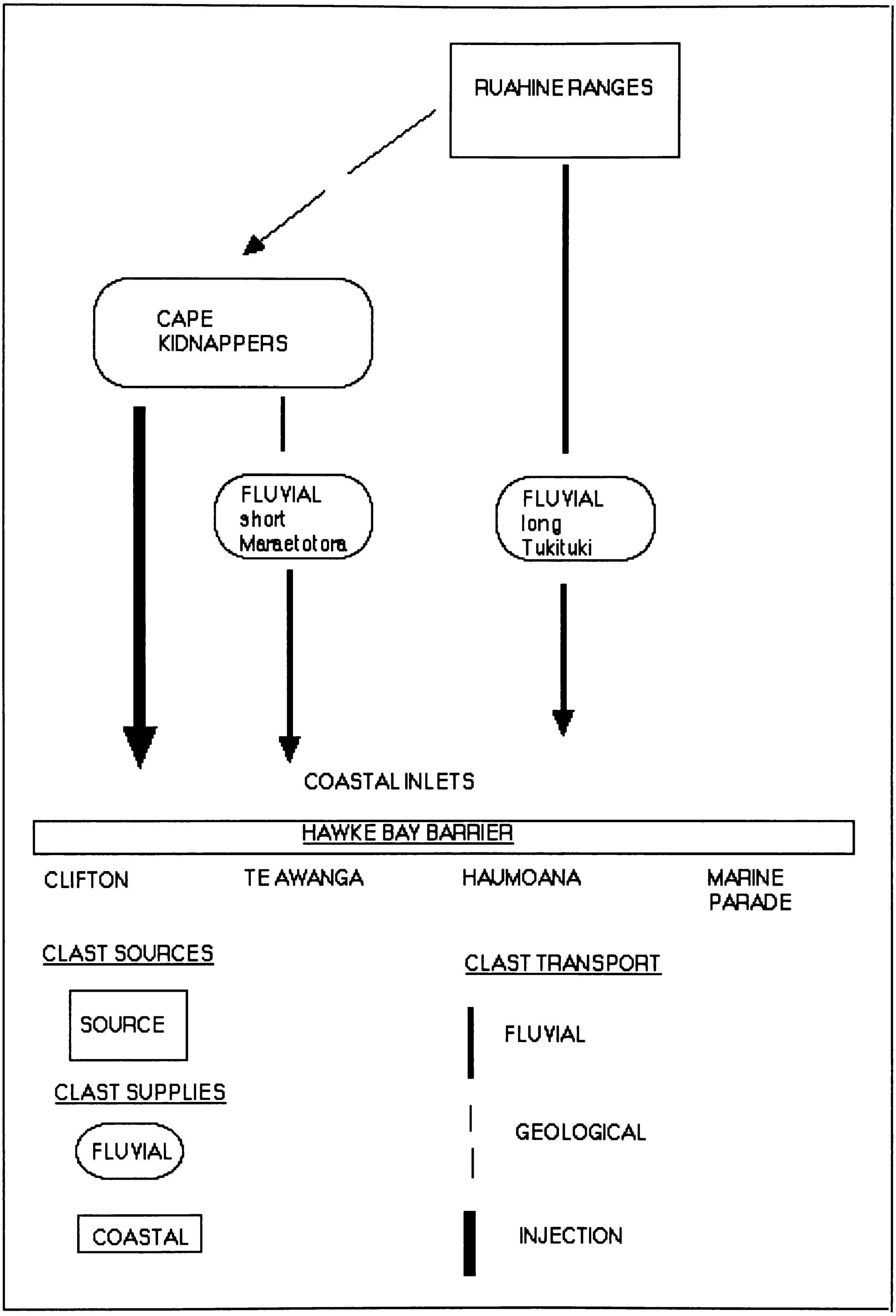
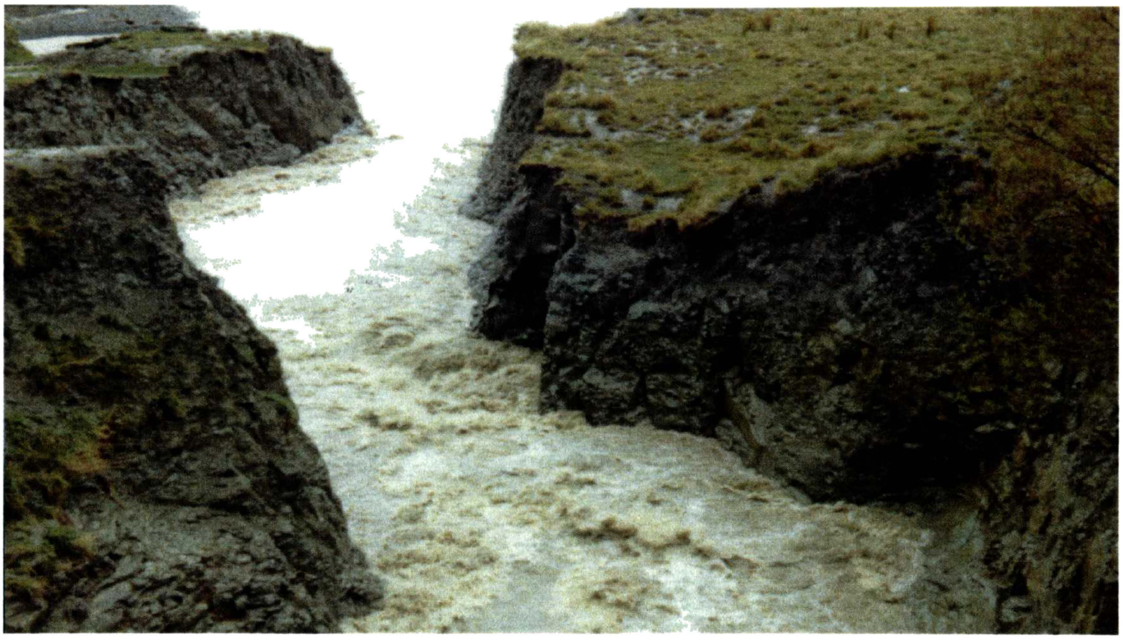


Figure 8.1. The Hawke Bay barrier clast source and supplies. The clast transport systems for clast modification are indicated.



(John White print 5)

Figure 8.2. Folger’s Lake, 3 September 1988. Upper Tukituki River, Ruahini Ranges, gravel source. Gorge cut into fresh greywacke, rock jointing suggests 120° ideal for production of discoidal clasts. Wakarara greywacke group, middle Jurassic (part of eastern North Island Torlesse greywacke). Greywacke is argillites and sandstones, massive sandstones, spilites, spores (KINGMA, 1962). Folger’s Lake 176° 13.3’ E, 39° 52.2’ S.

(John White print 23)

Figure 8.3. Cape Kidnappers, 13 May 1989. Colluvium gravel supply in wave swash, high water terrace cut. Detrital scree material some older and vegetated in foreground. Fluvial conglomerates darker grey layers in cliffs, lighter grey pumiceous material. Note extensive normal faulting. Scree slopes from rapid cliff rock release, pressure release and dilation. Uniform well sorted gravels in swash on fringing barrier.

As the distance increase from the supply so the modifications can be expected to become more noticeable so that along the course of the Tukituki River, and within the stratigraphic 'fluvial' gravels, viz Hawera and Castlecliffian, the likely clast modifications are: -

Fluvial Modifications

	Downstream →
Roundness	increase
Size	decrease
Sorting	increase
Discs	decrease
Spheres	increase
MPS	increase
OPI	increasing +ve

Just prior to discharge into the marine environment the river supply of large sized clasts should have the properties of: -

Well rounded
well sorted
few discs
greater number of spheres
greatest value MPS
greatest + ve value OPI.

As the clasts pass into the wave energetic environment and the distances increase away from the supply inlet, the greatest value MPS should rapidly decrease (from spherical to disc) and the OPI takes on increasing -ve values (DOBKINS and FOLK, 1970).

Clast Size and Forms Variation Alongshore in a Wave Energy Gradient.

The HB barrier beach is reflective, with a steep beachface and a sub-aqueous step. For example, from September 1998 to March 1999 the average Clifton beachface slope measured between MSL and the spring tide high water level was 0.1 whilst the sub-aqueous step slope was at the angle of repose as an avalanche face.

Figure 8.4 represents the expected clast changes in an alongshore direction within the wave energy gradient between Clifton and Marine Parade in the alongshore direction. The Cape Kidnappers promontory shelters Clifton from the prevailing southerly oceanic swell and the nearshore submarine platform of Castlecliffian conglomerate should exert relatively high frictional drag on north to easterly quadrant swell and locally generated wind fetch waves from the north to west quadrant. Marine Parade receives refracted high energy southern oceanic swell and the nearshore deeper waters with a loose very fine sand bed may have less relative frictional drag on the local fetch waves especially from the north and east, but sheltered by Scinde Island from the west to north-west fetch.

REFLECTIVE BEACHFACE

SEDIMENT CLAST PARAMETERS		
ROUNDNESS	HIGH	LOW
SIZE	COARSE	FINE
SORTING	GOOD	POOR
MPS	LOW	HIGH
OPI	HIGH NEGATIVE	LOW NEGATIVE
WAVE ENERGY GRADIENT	HIGH	LOW

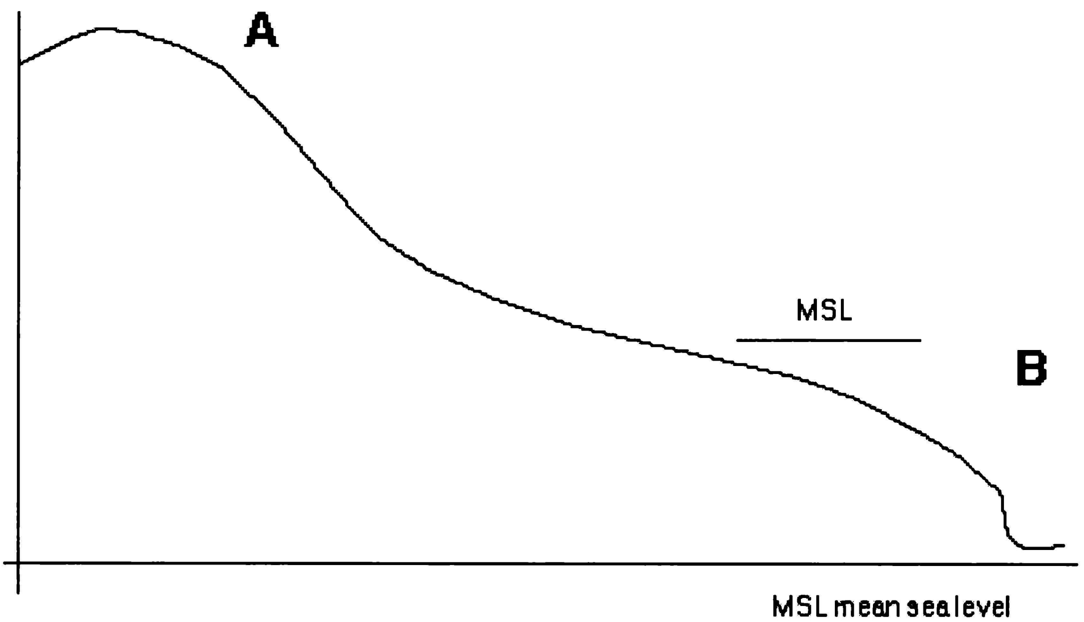
(After BRYANT, 1982; DOBKINS and FOLK, 1970; KING, 1959)

Note: MOUTZOURIS (1991) high energy beach size coarse, sorting "worse sorted".

Figure 8.4. The alongshore clast form changes and incident wave energy gradient, a conceptual model. MPS is the maximum projection sphericity and OPI is the oblate prolate index (DOBKINS and FOLK, 1970)

Clast Size and Form Across the Shore.

Figure 8.5 depicts the cross-shore expected clast parameter changes that should be relatively similar in the high and the low energy environments. The sediment textural relationship to the incident wave energy should show some pattern with seasonal wave steepness variation at a particular locality and for a longshore refracted wave energy gradient.



MSL mean sea level

CLAST PARAMETER	A BEACH CREST	B STEP TOP
ROUNDNESS	HIGH	LOW
SIZE	LARGE	COBBLE
SORTING	WELL SORTED	WELL SORTED
SKEWNESS	SYMMETRIC	NEGATIVE
KURTOSIS	HIGH POSITIVE	NEGATIVE
MPS	LOW	HIGH
OPI	NEGATIVE	POSITIVE

(after BLUCK, 1967; DOBKINS and FOLK, 1970)
(Note: MOUTZOURIS (1991) step toe coarse sediment worst sorted across whole beachface)

Figure 8.5 Cross-shore beachface clast roundness, size/sorting, skewness/kurtosis and form changes, as a product of selective sorting, a conceptual model.

8.5 Summary and Conclusions.

General models of the expected gravel textures to the HB are presented based upon findings in other ‘similar’ environments. Generally, the HB gravels have a well-defined greywacke source, the Ruahini Ranges, and two main identyfiable supplies to the contemporary coast. Both of the main supplies are ‘fluvial’ with the ‘geological’ Cape Kidnappers and the modern Tukituki River. These fluvial supply clasts should be of relatively small size, well sorted, spherical greatest value of +ve OPI and MPS. However, the Cape Kidnappers colluvium should be relatively poorly sorted, and it is suggested that in times of high river discharge the Tukituki River sediments may also be more poorly sorted.

In the cross-shore direction, the gravel sizes should be large towards the beach crest, from a cobble sized step, well sorted across the beachface, skewness becomes more symmetric towards the beach crest from negatively skewed step. The form parameters should arrange with the OPI more negative towards the crest from a positive OPI step, and the MPS becoming more low value towards the crest.

In the alongshore direction the low wave energy (Clifton) beach should have the finer gravels grading to coarser at the high wave energy Marine Parade. The alongshore grading of other parameters should also occur from a low wave to a high wave energy environment, namely sorting should grade from poorly sorted to better sorted and the OPI should grade from a low negative value to a high negative value and the MPS grade from a high value to a low value.

CHAPTER 9 LOWER BEACHFACE GRAVEL SIZE PARAMETERS.

9.1 Introduction.

This chapter examines three aspects of the lower beachface gravel size parameters. Firstly the sampling period trends, secondly at the event scale, and thirdly in a wave energy gradient.

Synchronous sampling could indicate some similar temporal changes to the beachface gravel population. Should temporal population changes take place then it could be possible some common results may exist at all, or some, sites, and that these results could be in response to the incident wave energy. The gravel sizes do not transport any great distance at times of relatively low energy, but in times of high energy they do transport and are rearranged by sorting processes. The gravel population at each site could therefore have similar responses to a given hydrodynamic 'event', for example high wave energy. High wave energy events are of relatively short duration and could produce similar results at all sites, for example storm gravels become either finer, or, coarser. Conversely, a drift to a 'common' state in periods of prolonged non energetic waves (lacuna) might be expected. In the alongshore wave energy gradient the high energy beach (Marine Parade) should be coarser and well sorted, and the low energy beach (Clifton) finer and more poorly sorted.

9.2 Sampling.

This chapter examines the gravel textural parameters at the lower beachface over an extended sampling period. The extended data are from September 1997 to April 1998, but this Chapter focusses on the short period September to December 1997 data. Surficial gravels from the lower beachface cusp horns were sampled at four sites, namely Clifton, Te Awanga Hall, Haumoana and Marine Parade. Within the long sampling period of 81 days, the sample sites were visited on average every 9 days. Between February 1998 and late March 1998 the beachface became sandy and the gravel sizes were not 'exposed' and sampling did not take place.

The HB grain size parameters for each sample were determined by the moment method statistics for the mean grain size (Phi), sorting (Phi) (MASSELINK, 1992) and skewness. The skewness parameter is the Fisher's measure (SWAN and SANDILANDS, 1995). The following sections are arranged by the statistical parameters mean grain size, sorting, and skewness.

9.3 Textural Parameter Methology.

It should be noted that the skewness class intervals used in this research follow FOLK (1968) as a verbal descriptive method only, for example 'strongly coarse skewed'. GARDINER and GARDINER (1979) point out that the FOLK (1968) graphic statistical methods produce the reverse skewness sign. For example the positive skewness of FOLK (1968) is negative using the moment method. Hence there can be confusion, however in this thesis all skewness parameters follow the moment method for example coarse (sediment size) skewness is negative moment skewness. Moreover, few gravel size frequency distributions are normally distributed, and are mostly bimodal.

Each long sampling period size parameter at each sample sites is measured by a linear least squares fit polynomial. The least squares fit does two things. Firstly it indicates the longer sampling period trend over the total sampling period (seasonal) and secondly, it highlights any short intersample trend over the sample dates (for example a storm event).

The McLAREN model (McLAREN and BOWLES, 1985) is applied to the temporal measurement of the HB gravel size parameters where the longer trend is the general gradient of a regression line, and the short trends can have oscillations with:-

1). Fluctuation, is the change of direction over a sampling period, for example a sediment mean grain size becomes either finer or coarser.

2). Continuous, no change of parameter direction sampling dates, for example the mean grain size continues to become either finer or coarser, for example the 'finer' state repeats.

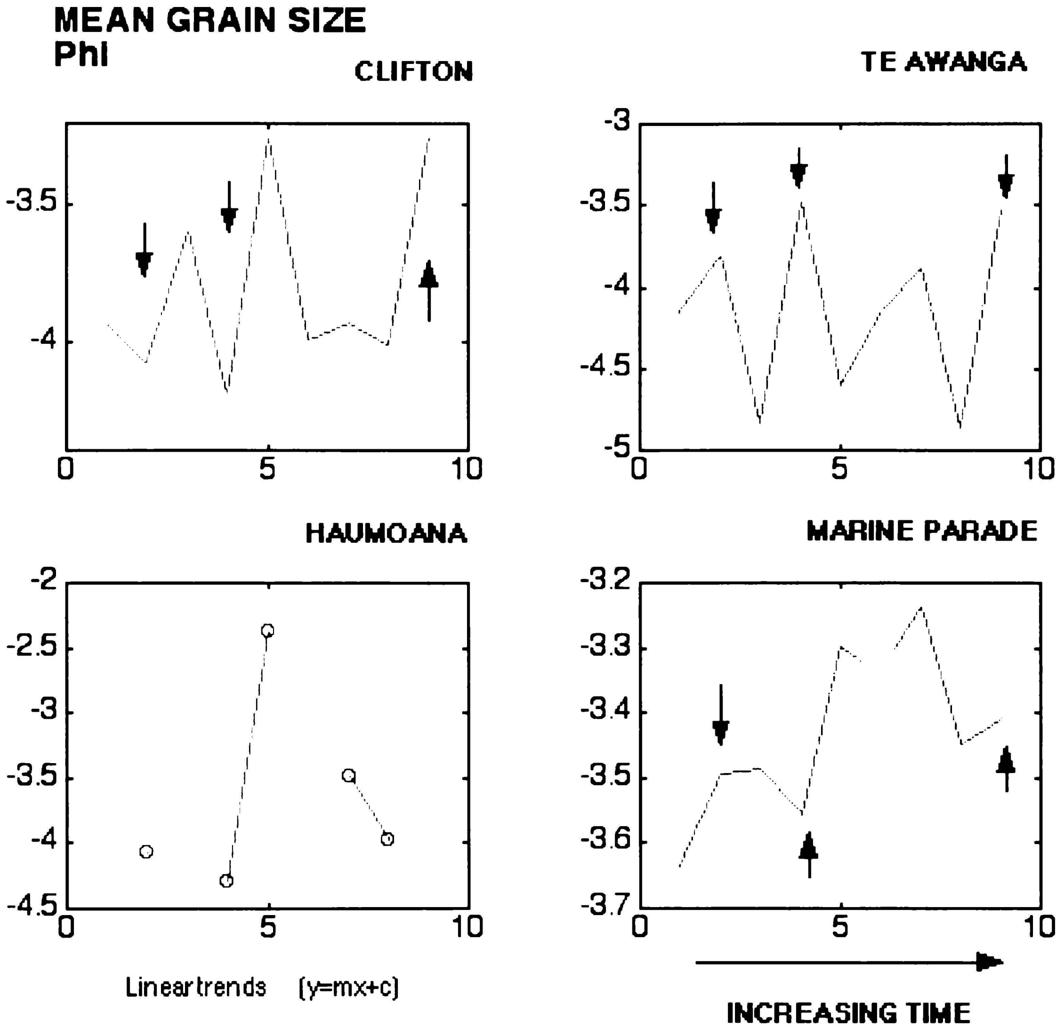
9.4 Results.

The grain size parameter trends September to December 1997 for each site are the mean grain size (Phi) (Figure 9.1); sorting (Phi) (Figure 9.2) and (skewness) (Figure 9.3). The verbal description for the skewness and sorting parameters are located in Appendix 5. Over the sampling period three high energy wave events occurred (breaking wave height = Hb > 1.0 m) on 27 September, 1997; 18 October 1997 and on 12 December 1997 dentified by '*' and a line-arrow on each Figure.

Appendix 6 has summaries of the breaking wave period (T_b) and height (H_b) data at the time of sampling the gravels and the gravel textural sizes statistical parameters.

Mean Grain Size (Figure 9.1).

The trend of the mean grain size at the sites indicates a general fining, including Haumoana on a purely visual estimate. The magnitude of the grain size (Phi) variation differs, where Marine Parade has low magnitude (narrower range of mean grain size variation), and Haumoana has a higher magnitudes (wider range of mean grain sizes). The difference between sampling times (the intersample trends) are defined later with a McLAREN (McLAREN and BOWLES, 1985) type classification. General observation shows most parameter changes fluctuate between sampling intervals. There are however a few examples of continuous parameter 'drift' states. These continuous states are, for example Te Awanga date 5 (2 November 1997) to date 7 (25 November 1997), where the mean grain size parameter continues to become finer over more than one sampling interval. Generally these continuous states do not occur at two or more sites simultaneously over the same sampling intervals. However, the sampling interval fluctuations can have similar trends. For example, between sample dates 4 to 5 (18 October to 2 November 1997), at Clifton, Haumoana, and Marine Parade the gravels became finer, but, at Te Awanga the gravels became coarser.



Linear trends (y=mx+c)

	m	c
Clifton	0.04	-4.01
Te Awanga	0.01	-4.20
Haumoana	-	-
Marine Parade	0.03	-3.58

Sample Dates

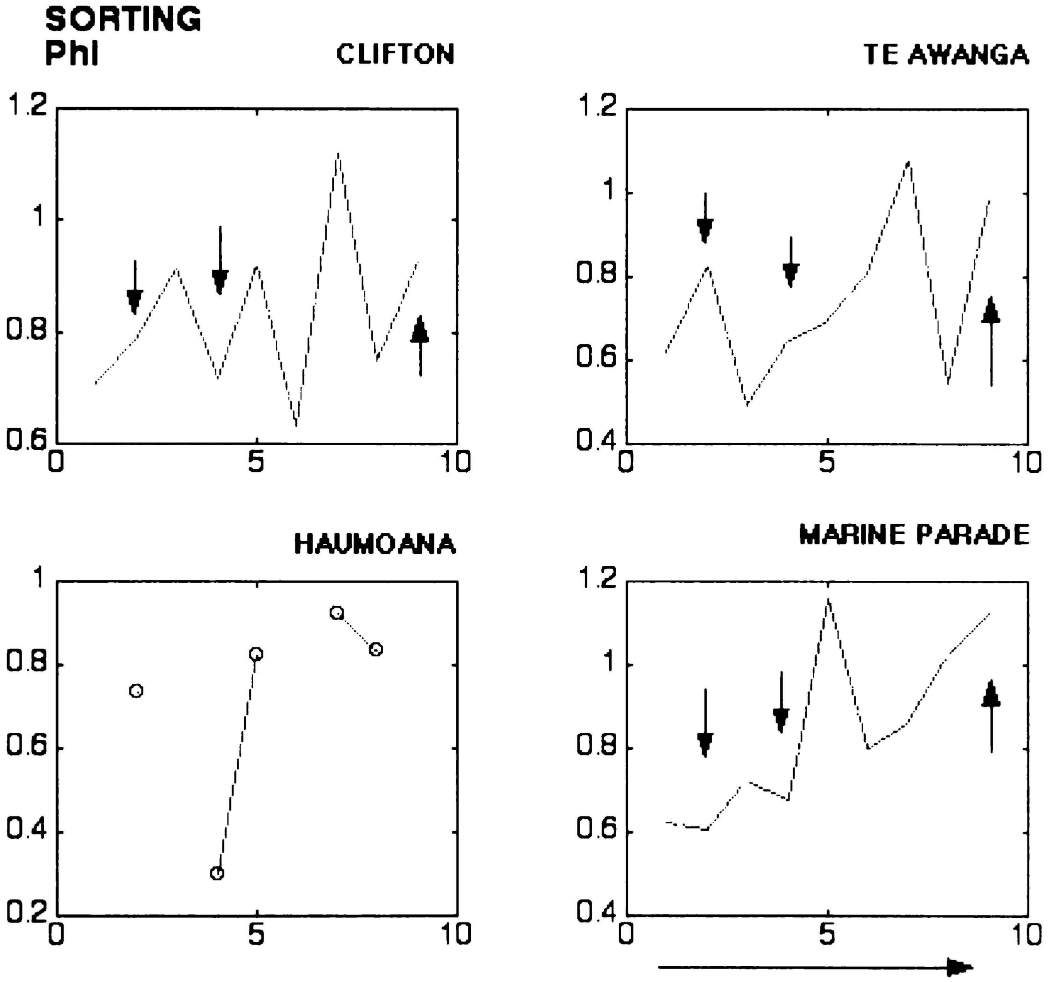
20 Sept 97	27 Sept 97 *
6 Oct 97	18 Oct 97 *
2 Nov 97	17 Nov 97
25 Nov 97	2 Dec 97
12 Dec 97 *	

* High energy (H_b) > 1.0 m ↓

Figure 9.1. Mean grain size (Phi) variations from 20 September 1997 to 12 December 1997. Gravels are from the lower beachface cusp horn. The long trend is shown by a linear least squares fit whilst the intersample trends show both fluctuating (for example Clifton sample dates 20 September 1997 to 18 October 1997) and continuous (for example Te Awanga sample dates 2 November 1997 to 17 November 1997).

Sorting (Figure 9.2).

The trend through the long sampling period at all sites is towards a more poorly sorted sediment. The magnitudes of sorting variation differ from a high magnitude at Te Awanga to low magnitude at Marine Parade, excluding date 5 (2 November 1997).



Linear trends (y=mx+c)

	m	c
Clifton	0.18	0.74
Te Awanga	0.03	0.58
Haumoana	-	-
Marine Parade	0.06	0.54

Sample Dates

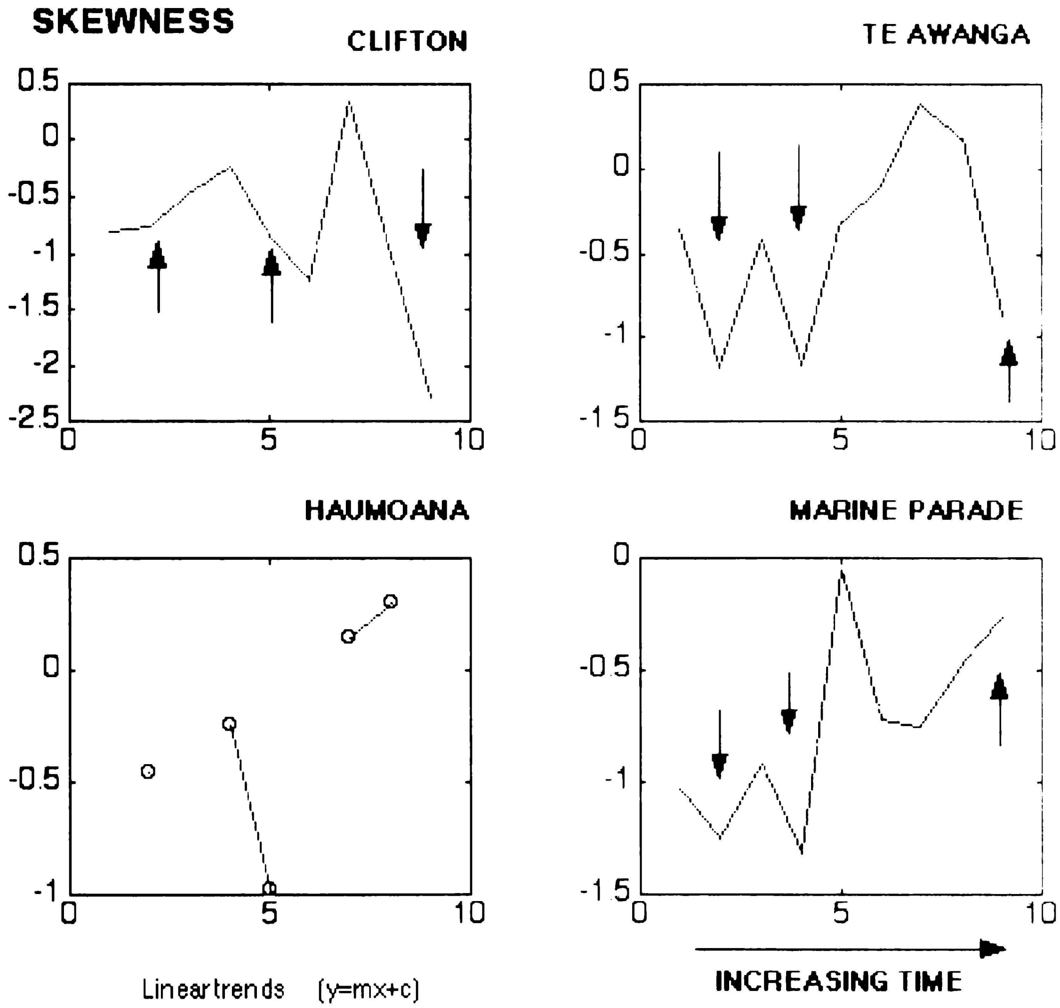
20 Sept 97	27 Sept 97 *
6 Oct 97	18 Oct 97 *
2 Nov 97	17 Nov 97
25 Nov 97	2 Dec 97
12 Dec 97 *	

* High energy(H_b) > 1.0 m ↓

Figure 9.2. Sorting (Phi)Variations of variations from 20 September 1997 to 12 December 1997. Gravels are from the lower beachface cusp horn. The long trend is shown by a linear least squares fot whilst the intersample trends show both fluctuating (for example Clifton sample dates 6 October 1997 to 12 December 1997) and continuous (for example Marine Parade sample dates 17 November to 12 December 1997).

Skewness (Figure 9.3).

Te Awanga, Marine Parade, and Haumoana have a long trend of a decreasing (negative) skewness Clifton is the only site where the skewness became increasingly negative. The magnitude of skewness variation is greatest at Clifton, and least at Haumoana.



Linear trends (y=mx+c)

	m	c
Clifton	-0.104	-0.297
Te Awanga	0.079	-0.826
Haumoana	-	-
Marine Parade	0.105	-1.282

Sample Dates

20 Sept 97	27 Sept 97 *
6 Oct 97	18 Oct 97 *
2 Nov 97	17 Nov 97
25 Nov 97	2 Dec 97
12 Dec 97 *	

* High energy (H_b) > 1.0 m ↓

Figure 9.3. Skewness variations from 20 September 1997 to 12 December 1997. Gravels are from the lower beachface cusp horn. The long trend is shown by a linear least squares fit whilst the intersample trends show both fluctuating (for example Westshore sample dates 20 September 1997 to 2 November 1997) and continuous (for example Te Awanga sample dates 18 October 1997 to 25 November 1997).

The Sampling Period Trend.

Based upon linear polynomials (except Haumoana, using visual trend) the sampling period trend descriptives for each HB site are:-

PLACE	Mean grain size (Phi)	Sorting	Skewness
CLIFTON	Becoming finer	More poorly sorted	Increasing coarser skew
TE AWANGA	Becoming slightly finer	More poorly sorted	Increasing finer skew
HAUMOANA	Becoming finer	More poorly sorted	Increasing fine skew
MAR PAR	Becoming finer	More poorly sorted	Increasing finer skew

MAR PAR is Marine Parade

Coarse textural size skewness is negative skew values; the fine textural size skewness is positive values (GARDINER and GARDINER, 1979).

These sampling period trends are placed into a McLAREN (McLAREN and BOWLES, 1985) qualitative model defined by the possible combinations of the three grain size parameters, mean grain size, sorting and skewness.

McLAREN and BOWLES (1985) suggest the two states "Case B" and "Case C" are characteristic of sediment transport and all other states are sediment lag deposition. These McLAREN sediment transport states correspond to (F, B, -), or state A, (a summer transport state, or, an energy increase state) and (C, B, +), or state G (a winter transport state, or, an energy decrease state) in the list reproduced below.

McLAREN's model has eight statistical parameter states defined by textural statistical parameters:-

A) finer (F), better sorted (B) and more negatively skewed (-ve),
B) coarser (C), poorer sorted (P) and more positively skewed (+).
C) C, B, -
D) F, P, -
E) C, P, -
F) F, B, +
G) C, B, +
H) F, P, +

Within the HB setting the sampling period trend states each site became over 81 days:-

	Final State (Summer)		Initial State (Winter)	
CLIFTON	(D)	F, P, -	(G)	C, B,+
TE AWANGA	(H)	F, P, +	(C)	C,B,-
HAUMOANA	(H)	F, P, +	(C)	C,B,-
MAR PAR	(H)	F, P, +	(C)	C,B,-

The underlined state(s) above correspond to McLAREN's sediment transport states.

These sampling period trends suggest for most sites there is no apparent net sediment transport, and sites are mostly lag deposits, except for the initial winter samples at Clifton. At this early time Clifton gravels were in a sediment winter transport state. This transport state would be the equivalent to SONU (1972) erosion types IV to II).

GILLÉN and PALANQUES (1996) suggest that if the sample sites become finer then they are depositional. This suggests the sites at Clifton, Te Awanga, Haumoana and Marine Parade are summer depositional beaches.

The long trend mean grain size rate of change, or the linear least squares fit graidient, is marginally greater at Clifton (especially sorting) than all other sites. The Marine Parade, Te Awanga Hall and Haumoana sites all have a +ve rate of change for all three textural parameters. Clifton is the only site with a -ve fit rate of change gradient for skewness.

9.5 The Intersample Trends (Fluctuations within the Sampling Period).

Intersample state grain size parameter fluctuations are frequent, however, continuous parameter states do occur. For example Marine Parade (Figure 9.3) has a prolonged increasingly positive skewness state between the sample dates 7 to 9 (25 November 1997 to 12 December 1997).

If the parameter fluctuation/continuity at sampling intervals are placed into a McLAREN model then:-

CLIFTON	TE AWANGA	HAU	MAR PAR	DATE
B	D		A	20/9-27/9 *
H	G		H	27/9-6/10
G	D		C	6/10-18/10 *
D	B	D	H	18/10-2/11
C	H		C	2/11-17/11
H	H		H	17/11-25/11
C	C	G	B	25/11-2/12
D	D		H	2/12-12/12 *

- these represent size parameters in high seas (Hb > 1.0 m)

Two main observations can be made:-

The parameter states can have what appears to be two end members:-

i). A fairly random temporal arrangement, for example Clifton where no state repeats more than twice, or,

ii). A more steady state, for example Marine Parade, where a state can repeat more than twice (state H).

Beaches can also all change to a similar grain size parameter state, where all sites change to state H (F, P, +) (sample dates 17 Nov to 25 Nov 1997).

This leads to an idea of textural state temporal stability, and apparently this is more common perhaps for some sample sites than others. There is also a possibility of long low energy periods, or energy lacuna, when beaches are able to drift towards a common parameter state.

McLAREN and BOWLES (1985) suggest energy increase should induce finer and more negatively skewed sediments and with expected poorer sorting by wave turbulence (BRYANT, 1982) the expected state is D. State D is finer, poorer sorting, negative skewness.

The HB size states recorded for high seas with (H_b) wave breaker heights greater than 1.0 m are:-

CLIFTON	TE AWANGA	HAU	MAR PAR	DATE
B	D		A	20/9-27/9 *
G	D		C	6/10-18/10 *
D	D		H	2/12-12/12 *

Of these there are matches, especially Te Awanga with all state D. The most frequently occuring states are H and D. State D is the high seas state and state H is the low energy lacuna state. States G, is associated with winter transport and possible accumulation (SONU, 1972; McLAREN and BOWLES, 1985).

The large variation of intersample fluctuations especially at Clifton suggest the gravel supply 'dominates' the wave sorting, and this would be expected at Clifton with a chaotic colluvial cliff fall process supply.

9.6 HB Gravel Sizes and the Wave Energy Gradient, the Gravel Supply and Sink.

The HB sample sites represent the sediment supply and the sink. In a high energy event these beachface sediment size parameter responses are:-

1). Supply. Clifton and Te Awanga.

Clifton gravels usually become coarser but can become finer, sorting is usually poorer but can become better, skewness is usually positive but can become more negative.

Te Awanga gravels invariably become finer, more poorly sorted, and have negative skewness.

2) Sink. Marine Parade.

Marine Parade gravel usually becomes finer but can become coarser, sorting usually becomes better but can become poorer, skewness is usually negative but can be positive.

3). Wave Energy Gradient.

The most conspicuous size parameter with a clear trend is skewness. At both Marine Parade and

Clifton the mean grain sizes and the sorting do have a drift, for example Clifton is always coarser and more poorly sorted than Marine Parade. Marine Parade gravel states were mostly -ve skewed, however, over the long trend the skewness had the steepest positive gradient with the gravel population becoming rapidly more positive. Conversely Clifton was -ve skewed on most sampling days and had a negative long trend gradient infering the gravels were becoming increasingly negatively skewed, i.e., a coarse lag.

9.7 Discussion of the Hawke Bay Lower Beachface Gravel Texural Parameters.

Previous studies examined the HB barrier clasts using the long axis (GIBB, 1973) and short axis (SMITH, 1984); both of these studies show a decreasing clast size, in the downdrift direction from Clifton to Marine Parade. This study uses the intermediate axis length to describe clast size parameters mean grain size, sorting and skewness, for the sample sites at Clifton, Te Awanga, Haumoana, and Marine Parade. These textural parameters can be arranged into McLAREN states, for example C, B, + (coarser, better sorted and more +ve skewness).

The HB gravel size parameters at individual sites can shift in different temporal dimensions, for example sampling period and intersample trends. Intersample parameters at an individual site can either alternate in opposite directions, or become more continuous over sampling time intervals. From the McLAREN (McLAREN and BOWLES, 1985) model the sites can show a 'random' pattern of states, where no sediment parameter state repeats, for example Clifton. A steady state can also be possible. For example at Marine Parade the gravel textural parameter states can repeat more than once, namely states H (F, P, +) and C (C, B, -). It is also poosible that all the beaches drift to a common state in a lacuna, or period of low wave activity. All beaches attained a state H 17 to 25 November 1997. It was also demonstrated that in high seas a beach can atain the same state each time, for example Te Awanga Hall became state D (F, P, -) on all three occassions when the wave height H_b was > 1.0 m.

The longer sample period trends are defined by a linear least squares model at a particular site, but when comparing the different sites they can be seen to have different gradients (where the linear trend gradient is either positive, or negative). Maximum gradients of sediment sorting at Clifton could be the nature of the sediment supply with wide ranging clast sizes supplied by the eroding Castlecliffian conglomerates. In winter the more energetic seas can sort the sediment mix, but in lower energetic summer seas the sorting becomes poorer. Skewness has a maximum positive trend gradient at Marine Parade and a minimum at Te Awanga so that the skewness is becoming more symmetrical (becoming more positive skewed, from a negative skew). Clifton is the only site with an increasing negative trend gradient (with skewness becoming more negative).

The HB-gravel size parameter changes could be related to wave power on two temporal scales and as a spatial arrangement. The two temporal scales are:-

1). Sample Period. Over a spring equinox there is a progressive change from high energy winter, to low energy summer.

2). Intersample. Over a high energy event, there is a progressive change from energy increase and the

erosion (selective removal) of sediment followed by a decrease of energy and accumulation of material.
And the spatial arrangements as:-
3). HB gravel sizes and the wave energy gradient, the gravel supply and sink.

If the 'y' axis intercept is a measure of the gravel size parameters then there are distinctive gradients alongshore of the gravel size parameters, but there are also local 'effects'. For example, the mean grain size (Figure 7.1) decreases from Clifton (-4.01 Phi) to Marine Parade (-3.58 Phi), but Te Awanga has -4.20 Phi. Similarly the sorting becomes increasingly well sorted between Clifton and Marine Parade, likewise skewness becomes increasingly more –ve between Clifton and Marine Parade.

For increasing wave energy BRYANT (1982) suggests when sediment supply (availability) is plentiful sediments become coarser, and with limited availability the sediments become finer and later become coarser on accretion. The parameter characteristics shown by the HB beaches suggests generally the sediment supply is available, but it can vary and become limited, and the sink tends towards sediment availability limitation.

At synchronous sampling sites over an intersample interval some sites may become simultaneously finer, for example Clifton, Haumoana, and Marine Parade between 10 October 1997 to 2 November 1997, but, over the same interval Te Awanga became coarser. Therefore, if the GILLÉN and PALANQUES (1996) model is invoked, three beaches are accretional, (become finer) and one erosional (coarser) over the same time interval with a high seas (Hb > 1.0 m) event.

Skewness gives some measure of a frequency distribution bimodality (SONU, 1972) and as a distinguishing statistic between "low-energy functions" and "high-energy functions" (McLAREN and BOWLES, 1985). SONU (1972: Figure 3, p 854) demonstrates for grouped data parameters that as the median grain sizes become coarser the skewness becomes increasingly negative. The Clifton site is contrary to this. McLAREN and BOWLES (1985) suggest that as the transport energy increases the sediment in transport becomes more negatively skewed leaving an increasingly coarse grain lag at the source site, and as the transport energy decreases the sediment at a depositional site becomes more positively skewed (where the mean displaces from the median towards the finer grain sizes). Marine Parade conforms with this finding, but both Clifton and Te Awanga can become more –ve skewed, but can also become more +ve skewed, and not synchronously, for example sample on 12 December 1997. SAHU (1964) suggests negative skewness (where the mean displaces towards the coarser side of the median) can result when the velocity of depositing agent was greater than average, or the velocity of depositing agent operated over a longer time period than average, or high velocity fluctuations occurred more than average.

Again Marine Parade agrees with these findings. Generally when the wave turbulence increase, vis. In storms the gravels become –ve skewed, but not always, for example Marine Parade, however, Te Awanga Hall does always become more –ve skewed.

To test these 'anomalous' size parameter changes, and the possibility of a relationship to the sediment availability for transport further sampling was carried out. Cross-beachface gravel sampling may demonstrate the onshore transport of coarser sizes to the upper swash, therefore the low water sites become depleted of large gravel. Hence the sediment volume changes may relate to coarsening, or fining of beachface gravels where the fining is erosional and a profile becomes concave up, or coarser and a profile becomes convex up.

Sediment availability within transport systems may have large volume changes when a high seas event occurs. With increased sediment in accumulation (convex up profile) the gravel sizes should become coarser with the SONU (1972) model, or perhaps finer ((GILLÉN and PALANQUES, 1996). With limited sediment volume availability within a transport system the change should induce rapid coarse size transport resulting in a fine lag and an erosional beach (concave up).

9.8 Conclusions.

The Intersample Trends.

1). Intersample trends can have two end members where samples can either have rapidly fluctuating textural parameters, or they become continuous. Fluctuations appear closely associated with high energy events, and the continuous intersample trends more associated with prolonged periods of a low energy lacuna. The continuous parameters suggest the gravel sizes can become more steady state.

2). By placing the textural parameters into a McLAREN model (McLAREN and BOWLES 1985) sites can can be observed to repeat textural states. However, some sites did not repeat states more than twice, for example Clifton. This could be a function of the 'chaotic' sediment supply, coupled with greater variability of the incident seasonal wave climate.

3). Beach gravels do not all respond with similar parameter changes for high energy events (H_b > 1.0 m). Generally for any given event the beaches do not becomes either finer or coarser and individual beaches do not always respond with an identical parameter state, except for Te Awanga. The Te Awanga gravels responded with state D (finer, more poorly sorted, increasing negative skewness), for all three high energy events. Note that state D was also the most common response with the other beaches when H_b > 1.0 m. Beaches can also drift into a common state in low wave lacuna, for example all became state H ((F, P, +) in late November 1998 after nearly 4 weeks of low wave activity. Clifton did not repeat a state more than twice. On the other hand Marine Parade repeated states more than twice, with state H.

The Long Sampling Period Trends.

4). The long trends can either all have a similar parameter trend, or not, for example the mean grain size at all sites becomes finer over the 81 day sampling period Skewness becomes increasingly positive (increasing finer grain size skew), except for Clifton where gravels become increasingly negative (increasing coarser grain size skew). The sorting parameter at all sites has an increasing poorer sorting. BRYANT (1982) suggests for sheltered, reflective beaches, the sorting coefficient is stable (small change of the parameter over a sampling period). The HB beachfaces can show some similarities to BRYANT (1982). Stable site characteristics occur at Te Awanga (sheltered sink), whilst greater change takes place at Marine Parade (with the latter a high energy sink site. Arranging the size parameters into a McLAREN model (McLAREN and BOWLES 1985) the long trend at most sites is for continued lag type deposits. Only Clifton showed a transport sediment state, and this only at the onset of the sampling period (in late winter).

5). Over the sampling period the long trends suggest seasonality (vernal equinox) may be a factor. The best example is Clifton which begins with a winter transport state and ends in a summer lag state. Most sites have winter and summer characteristic where the winter gravels are coarser, better sorted and more sites have negative skewness, and the summer gravels tending to be finer, more poorly sorted and have more sites with positive skewness.

The variation of the parameters shows that Haumoana has the greater variation of mean grain size, which may be indicative of an 'eroding' beachface undergoing landward roll-over.

3). HB Gravel Sizes and Gravel Supply and Sink and Wave Energy Gradient.

6). As the sediment reworking continues over a longshore transport system it would be expected, as expressed in the McLAREN (McLAREN and BOWLES 1985) model that the sediments would become finer and more negatively skewed. In HB the Marine Parade (those gravels in both the greatest energy environment (swash zone) and over the longest distance from the supply) sediments do become finer but they also become more +ve skewed, however, this is over a change from a winter negatively skewed state. At Marine Parade the change of skewness could be related to a coarse winter lag being infilled by increasing summer finer gravel. Indeed the sorting does rapidly become poorer and the mean grain size finer.

7). Viewing the long trend from the polynomial least squares fit to the gravel textural size parameters the results are not as expected. The least squares gradients vary between the supply and sink sites, but what is interesting is the gradient slopes, measuring the rate of change. At the supply site (Clifton) the gradients are steeper than that at the sink (Marine Parade). Clifton would receive a greater quantity of mixed sized sediment ranging from cobbles to very fine gravels. Clifton also has a low wave energy to sort material. Thus the 'sorting'of material could be expected to be low. The low sorting rate would show as a low least squares gradient fit to the temporal data. Results show Clifton to have the steepest gradient fits, especially the mean grain size and sorting parameters, and the only negative gradient to the skewness.

This suggests that the sorting of material at Clifton is markedly good, or that the supply of material from the Cape Kidnappers cliff-line was less than usual. What-ever, there remains a strong 'seasonal signal' at Clifton between the coarser, well sorted winter and the fiiner better sorted summer. The relatively low rate of sorting at Marine Parade could be the material is already 'well sorted'. However, the variations of the parameters are slightly greater at Clifton which would also suggest the sorting of the Marine Parade material is already 'established'.

8). Fluctuations induced by intersample variations about the long trend gradient support the concept of sediment supply swamping the 'sorting' signal. Clifton has the greater fluctuations compared to Marine Parade, and this would be expected given the infrequent and chaotic supply from cliff fall colluvium. Further because Clifton is within a low wave energy environment the gravel sorting 'capacity' is less than that at the high energy Marine Parade. This is a classic supply effect controlling the sorting as postulated by McLEAN and KIRK (1969) for an erosive South Island MSG beach.

9). If the 'y' axis intercept is meaningful then the following conclusions can be drawn. Clifton is coarser than Marine Parade, but Te Awanga is the coarsest. This suggests that a longshore gradient is present but 'local' effects are also present. The gravels are more poorly sorted at Clifton than Marine Parade and there is a longshore gradient towards more well sorted gravel. Negative skewness increases from Clifton to Marine Parade. With increasing time, viewing the rate of change gradients. There is however a strong reversal of skewness. Marine Parade became the most +ve skewed whilst Clifton remained -ve skewed, and with increasing –ve skewness from the least squares fit gradient. This suggests the gravel skewness parameter is sensitive to the summer decrease of wave turbulence at least at Marine Parade, and Te Awanga Hall with 'deposition' of fines. But at Clifton, the decrease of wave turbulence is is not a factor for gravel 'sorting' and the supply continues to swamp the skewness signal. Fines deposit, sorting gets poorer and skewness increasingly –ve, which suggests the winnowing of fines from Clifton.

CHAPTER 10 BEACHFACE RESPONSE DURING A "MODERATE SEAS" EVENT.

10.1 Introduction.

This chapter examines the beachface gravel size parameters for a moderate 'storm' seas event which impacted the southern Hawke Bay coast late September 2000. Whilst Chapter 9 demonstrates that size changes took place along the southern Hawke Bay lower beachface over some four months, it is not certain what the cross-shore textural parameter changes are, either alongshore in a wave energy gradient, or at a specific site. For example, in an erosional event what are the alongshore textural parameter 'gradients' at the low and high water?

The aim of this chapter is to document the gravel textural sizes associated with a moderate sea 'erosional' event and the associated morphodynamics at three sites, namely Clifton, Te Awanga Hall and Marine Parade.

Sampling.

Southern Hawke Bay beachface morphodynamic events are associated with energetic wave events, namely 'erosion' and accretion. In this Chapter measurements of the beachface cross-shore transverse profile (beachface slope) and the breaking wave steepness, are associated with the gravel textural sizes. Sampling took place over a moderate energy event that eroded the HW ridge zones, except Marine Parade which was a veneer accumulation. Gravel sampling was carried out to represent the LW level and the HW run-up level zone.

The Moderate Wave Energy Event.

The 'erosional' wave conditions prior to the experiment on 26th September 2000, (Figure 10.1) were plunger erosional waves. The three sites examined were Clifton, Te Awanga Hall and Marine Parade. At these three sites, gravel sampling of the high and low water positions took place. Sampling was for an 'erosional' event, and indeed was erosional at Clifton and Te Awanga, but not completely erosional at Marine Parade. At Marine Parade, the lower beachface was erosional but the upper beachface was depositional. A concave 'winter' profile, developed at the sites; sequels and annotated photographs, Figures 10.2, 10.3 and 10.5, show the sample sites at Clifton, Te Awanga Hall and Marine Parade. Erosion is from high water sapping and sediment avalanche at an antecedent HW ridge and accretion is overtop deposition at Marine Parade (the sink site).

(John White print 7)

Figure 10.1. Te Awanga Hall, 26 September 2000, 1110, low tide at 0940, 0.1 m. The breaking wave height (H_b) 1.5 m and wave period (T_b) 14 s. This photograph realises a relationship between breaker type, water depth and beachface slope. The incident wave is plunging just seaward of the beach step, at the step a trapped wave has a standing wave breaker. In the foreground the breaker turbulence is the result of beachface backwash return flow meeting the standing trapped wave, this type of interaction invariably leads to a surging or collapsing 'wave'. The turbulence has characteristic wave front ruffling with many small wave crests (suggesting strong fluid shear). The backwash transports sediments to a step depositional fan where water depths shallow, hence the wave break can occur further seaward. Off the cuspate LW horns the water depth increases forming a hole, hence the wave break can occur further to landward. The hole could be scouring from laterally flowing currents from adjacent fans.

10.2 Results.

The three sample sites were sampled on 28 September 2000. Sampling was synchronous with sites sampled in a short time interval. This event consisted of moderate high seas, 1.5 m breaking wave height with a 1.7 m spring tide maximum.

The data for this event are: -

1). Tides and incident wave characteristics. Wave steepness (B_s), wave-breaking height (H_b), breaking wave period (T_b) summarised in Figure 8.4, and these have an interrelationship to the morphodynamics via the beachface slope (β) and Iribarren number (ξ) (BATTJES, 1974).

2). Cross-shore transverse profiles, for each site (sampled at slightly different times, see Figures 10.8 and 10.9) before, during and after sampling the gravel population, Section 9.3. The 'after' profiles and the morphodynamic parameters assist in showing the continuity of the beach system, which was the continued erosion on the beachfaces.

3). Gravel size parameters from the low and high water sample sites (Figure 10.8).

(John White print 9)

Figure 10.2. Clifton, 28 September 2000, 1055 (Low Water 1134, 0.0 m). Between August and September, accretional gravels deposited as an overwash on the HW ridge (to the height of the Naio tree, right foreground). This was the antecedent HW ridge. At the time of sampling the HW ridge underwent sapping erosion. There was accretion at the lower beachface platform with dark (wet) grey LW cusps. The subaqueous step was also accretional, with material possibly from the HW ridge and the inshore apron.

Tides, Incident Waves and Morphodynamics.

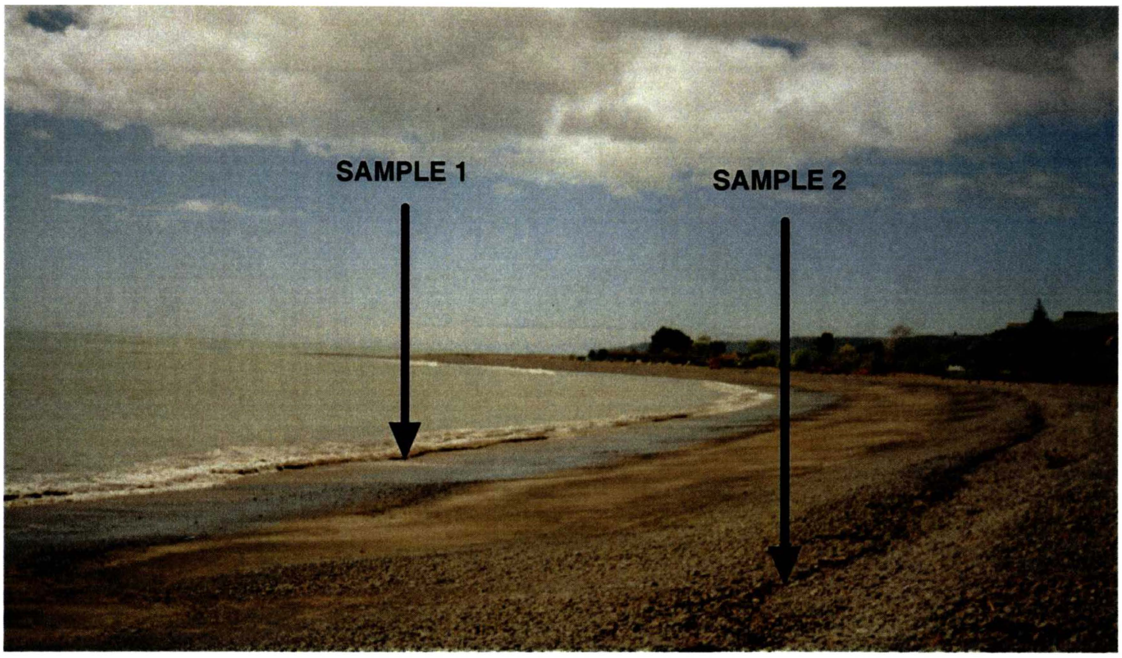
The tidal water levels (TIDE TIMES, 2000) can be split into periods before, during and after gravel population sampling. The beachface slope, wave steepness and Iribarren number are summarised in the same time split.

1). Before.

Before the gravel population sampling, on the cross-shore transverse profiling date 15 August 2000 the neap tide ranged 1.5 m to 0.3 m. At the end of August and early September, the spring tide ranged 1.8 m to 0.0 m.

2). During.

Over the sampling period, the tidal water levels ranged from an early springs (20 September 2000) of 1.6 m to 0.1 m; to 1.7 m to 0.0 m (maximum springs) on the gravel sampling date (28 September), Figures 8.2, 8.3 and 8.5. This tide was a short flat tide (maximum spring tide height 1.7 m over 5 days). The wave conditions at the onset of gravel sampling were associated with an atmospheric low pressure with rapid pressure increase related to a cold air rain front (25 September 2000) with some 60 mm rain (per. comm., Mike Pudney), some 1% of coastal trees were wind damaged (broken branches).



Sample site localities Sample, 1 Low Water cusp horn; Sample 2, high energy High Water ridge.

Figure 10.3 Te Awanga Hall, 28 September 2000, 1110, low water 1134. Gravel sampling beachface conditions. Sample labeling represents proximity only with actual sites closer to the observer. The breaking waves have more surging-collapsing types of characteristics. The HW beachface gravels represent a lag. These gravels result from high tide wave sapping at the base of the antecedent upper beachface HW ridge. Sapping involves wave induced instability at the base of the HW ridge steep face whence avalanche gravels transport. The high tide waves remove and downcombe some of these avalanche gravels leaving a lag deposit. At LW the cusp gravels are a composite of downcombed gravels, some from the HW ridge, some possibly from the eroding beachface swash zone, and gravels exhumed from the accumulating sediments at the morphodynamically accreting step. These LW gravels are 'sorted' into a cuspate morphology.

3). After.

Tidal water levels passed through a neap to an early springs of 1.6 m to 0.2 m (14 October 2000). Hence, the gravels sampled represent those subjected to a high energy seas coupled with a spring tidal maximum. Table 10.1 presents the wave conditions up to the 14 October 2000 and the morphodynamics of beachface slope (β), wave steepness (B_s), and Iribarren number (ξ) are included for comparison to the results for a high-energy event (Chapter 11). Chapter 12 combines the morphodynamic parameters for the moderate and high-energy events.

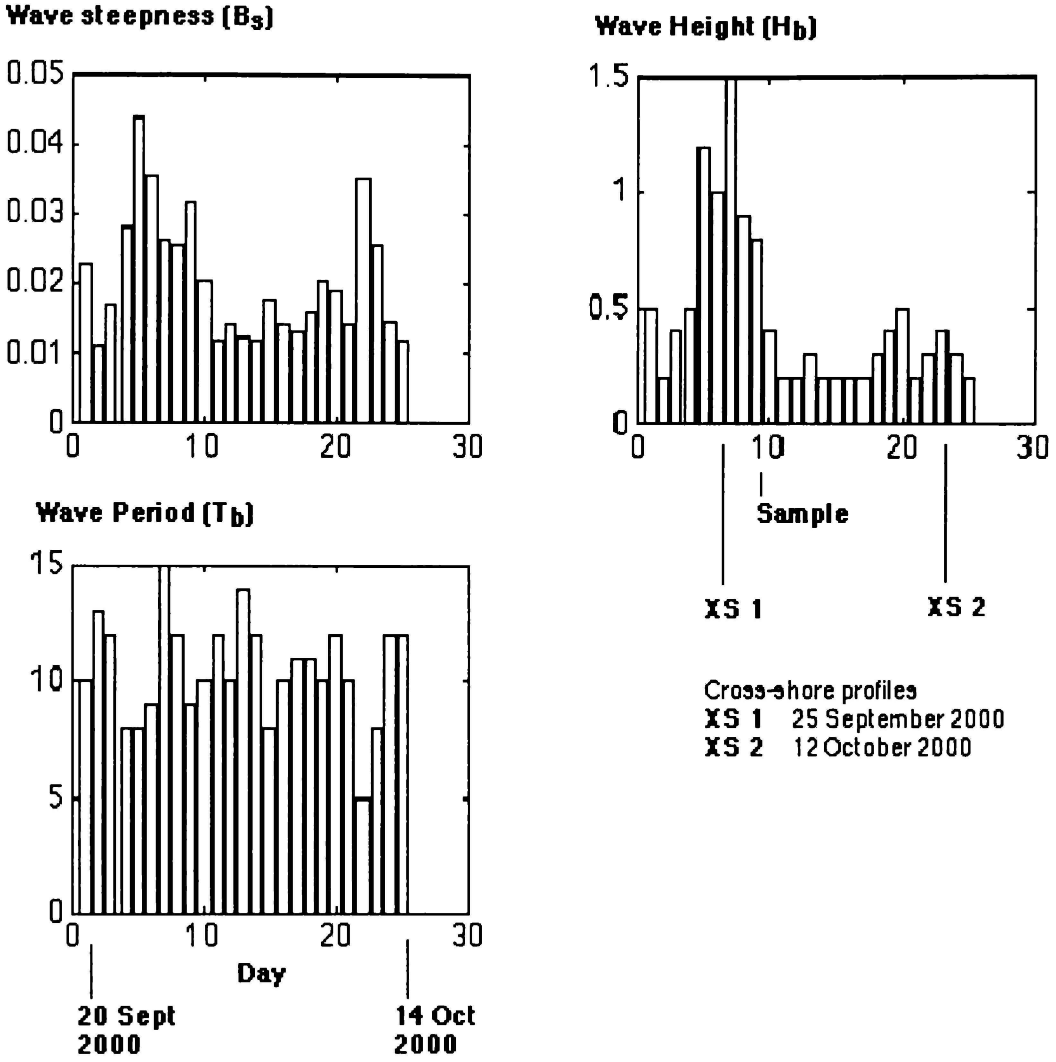


Figure 10.4. Wave parameters 20 September to 14 October 2000 over a moderate wave Energy erosion event. The parameter averages over the data period in the histograms are for wave steepness (B_s) 0.02; wave height (H_b) 0.46 m, and period (T_b) 10.5 s.

Pre-histogram parameters for August are for 15 August 2000 (first transverse cross-shore profile date) are breaking wave steepness (B_s) 0.015; wave height (H_b) 0.3 m, and period (T_b) 14 s.

Average (all) August parameters are: - (B_s) = 0.024; (H_b) =0.67 and (T_b) =11.19.

(John White print 16)

Figure 10.5 Marine Parade, 28 September 2000, low water 1225. Gravel sampling conditions. Overtop seaweed strand line along barrier crest. Recent deposition gravels are soft. Incident wave is inshore crest breaking. On the beachface, a range of breaker types from a near observed dissipating plunger bore actively transporting sorted gravels up the beachface. View north towards Napier port breakwater. High-energy site, a sediment sink site. Gravels are taken for the Westshore renourishment the 'borrow' site is nearer to the port

The beachface slope (β), wave steepness (B_s) and Iribarren numbers (ξ) are: -

	15 August 2000	25 September 2000	12 October 2000
Beachface slope/site			
SUPPLY			
Clifton	0.096	0.0904	0.0829
Te Awanga Hall	0.1038	0.0954	0.0762
SINK			
Marine Parade	0.0935	0.1025	0.087
Wave steepness	0.015	0.035	0.0252
Iribarren numbers			
SUPPLY			
Clifton	2.553	1.030	1.312
Te Awanga Hall	2.760	1.087	1.206
SINK			
Marine Parade	2.486	1.168	1.377

Cross-shore Transverse Profiles.

There are slight sampling differences because of the sea and weather conditions over the gravel sampling period. The cross-shore transverse profiles are arranged for the: -

1). Supply (Figure 10.6) Clifton and Te Awanga, and

2). Sink (Figure 10.7) Marine Parade.

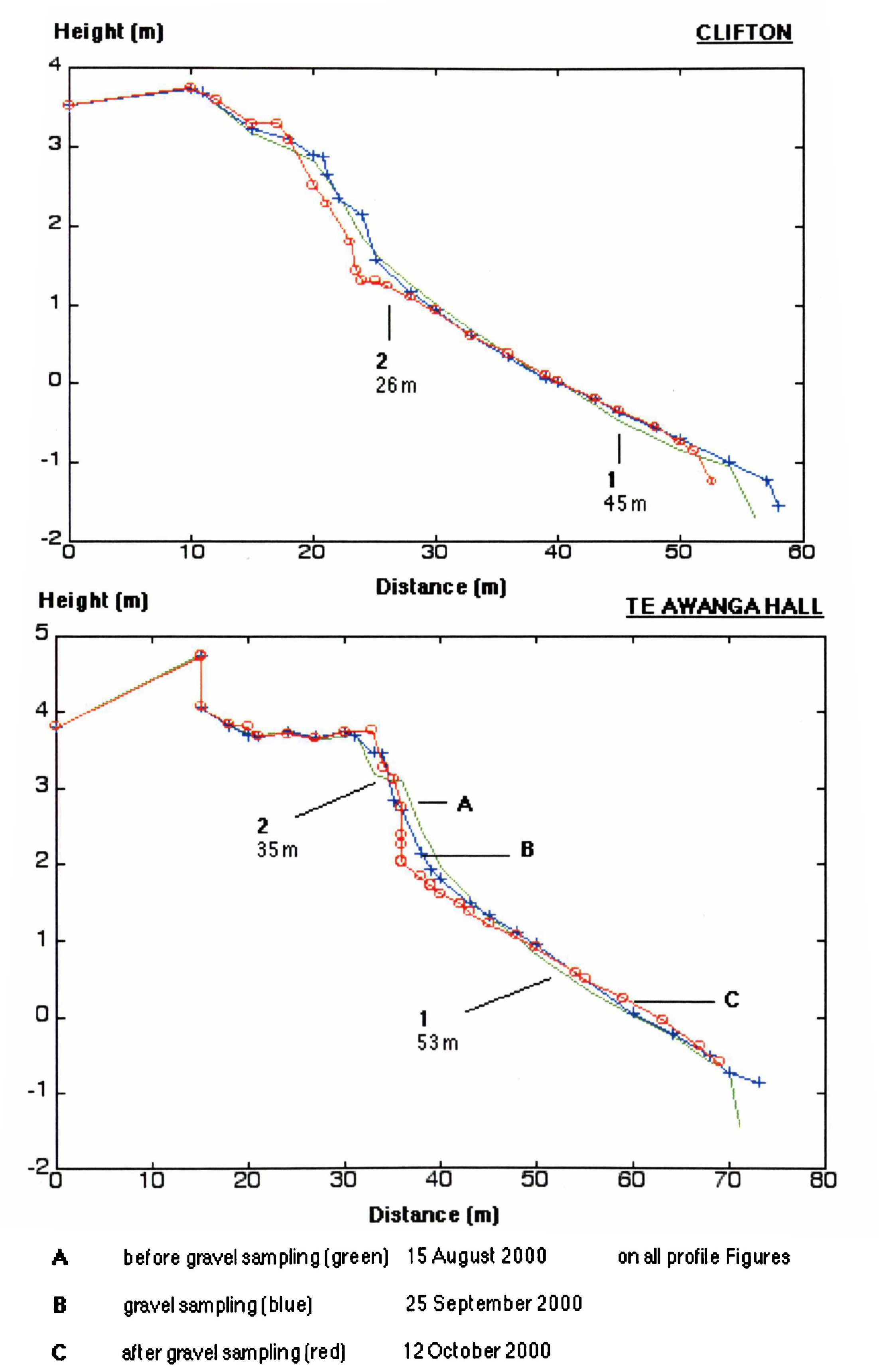


*Figure 10.6. Gravel supply cross-shore transverse profiles and gravel sampling sites (28 September 2000) at Clifton and Te Awanga Hall. Gravel sampling sites are **1** and **2** with cross-shore distances in parenthesis.*

The gravel sampling sites are indicated on Figures 10.6 and 10.7.

Some similarities of morphological change are present at all sites identified by the cross-shore transverse profile elevation changes, namely the reduction of the sediment volume and especially at the HW ridge. The most readily recognisable morphological responses in a chronological order are: -

1). August and September, (Figures 10.6 and 10.7, profiles **A** and **B**.) the sediment volume changes were small for the supply profiles and larger for the sink profile.

Supply profiles have the greatest changes at the sub-aqueous step shown by the greater horizontal and vertical increases as sediments accrete. Beachface elevation changes also suggest an accretional ridge at Te Awanga Hall at some 0.6 m (aMSL).

The sink profile step was erosional, although no data is available for Marine Parade step owing to the high seas; Marine Parade has a distinctive erosion of an antecedent HW ridge (at some 60 m from BM). It is possible that some of this ridge sediment transported up beach in the moderate seas event to accumulate at gravel sample site 2 as a reworked HW ridge gravel facies.

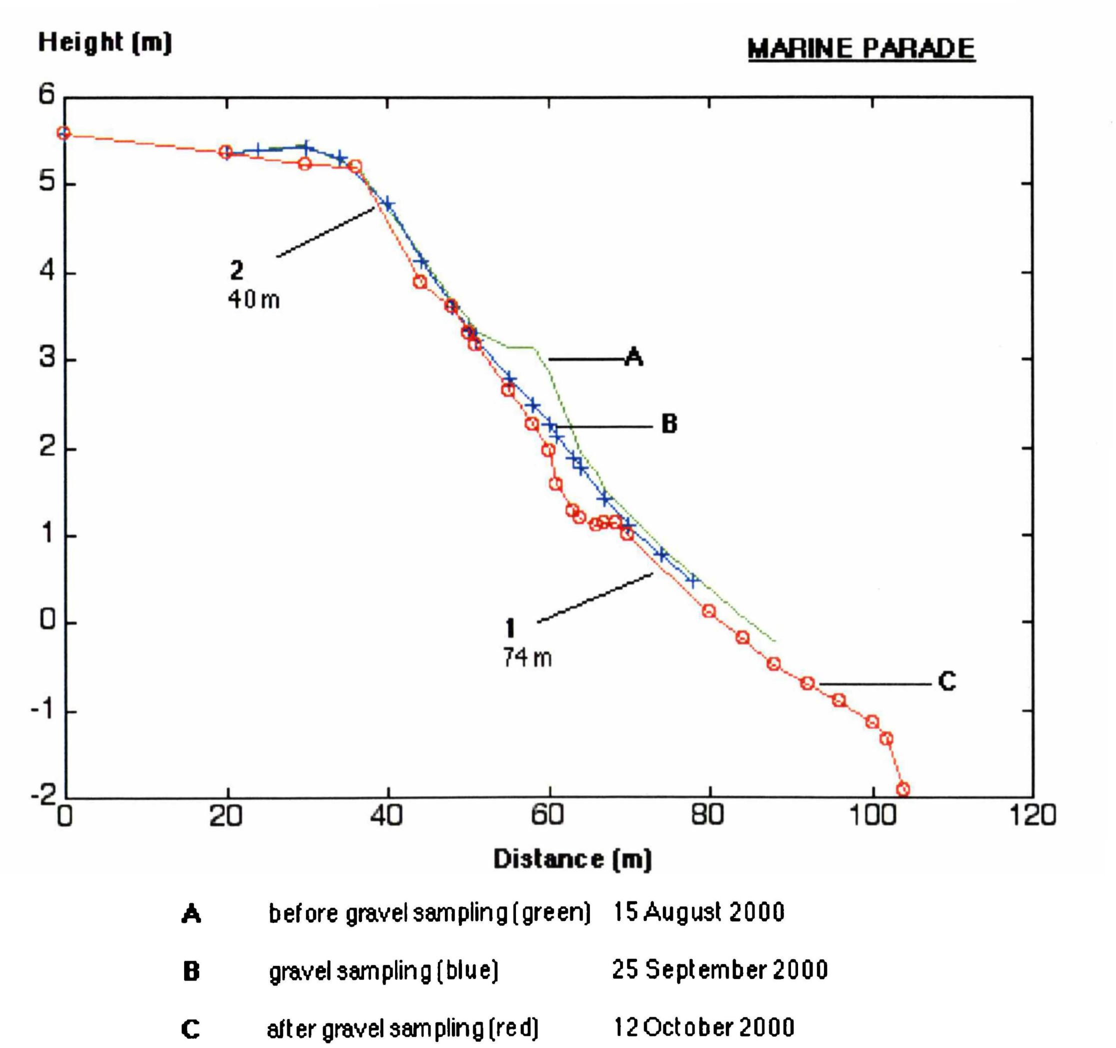


*Figure 10.7. Gravel sink cross-shore transverse profiles and gravel sampling sites (28 September 2000) Marine Parade. Gravel sample sites are **1** and **2** with cross-shore distance in parenthesis.*

These 'before' sampling changes result from a short high seas event between 18th and 20th August when the wave energy increased to a wave steepness (B_s) > 0.3 and wave height (H_b) > 1.0 m, and neap tidal levels ranging 1.5 m to 0.2 m. This 'before' event induced overtop deposition at Clifton, Te Awanga Hall, and Marine Parade.

2). Following this short 'before' event and up to the time of gravel sampling the wave conditions decreased. This infers that up to the time of sampling the gravels, the beachface conditions remained stable and the samples represent the changes that took place in response to a moderate energy event on a waxing spring tide.

3). At the time of gravel sampling the transverse cross-shore profile shapes were not identical, with: -

supply		
	Clifton	concave
	Te Awanga Hall	convex
sink		
	Marine Parade	concave

Gravel Textural Changes During a Moderate Wave Energy Event.

Gravel samples examine the 'effect' of a moderate wave energy event eroding a profile morphology. Samples represent a HW ridge sap at the supply sites and an accretion at the sink, and a LW accretional proto-cusp The gravel textural size analysis discussion is the general supply and sink characteristics, the cross-shore supply and sink and the alongshore supply and sink.

General supply and sink characteristics.

1). Supply.

i). Clifton, (Figure 10.2). Gravels from HW are lag depositional composed of material sapped from the antecedent HW ridge whilst the LW gravels are probably a mixture of downcombed HW sap gravels and exhumed from the accreting step.

ii). Te Awanga Hall, (Figure 10.3). Gravels sampled at HW are lag gravels from the sap erosion of the antecedent HW ridge and at LW the sorted, downcombed and possibly reworked gravels exhumed from the accretionary step.

2). Sink.

iii). Marine Parade, (Figure 10.5). Gravels sampled at HW are accretional gravels, and at LW are sorted downcombed and possibly exhumed from the erosional step.

Figure 10.8 summarises the gravel size parameters during a moderate seas event where the samples represent an 'erosion' facies and are lag depositional. By placing these size parameters into a McLAREN model (McLAREN and BOWLES, 1985) the size parameter changes relative to each other in a cross-shore direction are: -

SITE	McLAREN MODEL (state)	
	High Water	Low Water
CLIFTON	C, P, +ve (B)	F,B,-ve (A)
TE AWANGA	F, B, -ve (A)	C,P,+ve (B)
MARINE PARADE	C, P, -ve (E)	F,B,+ve (F)

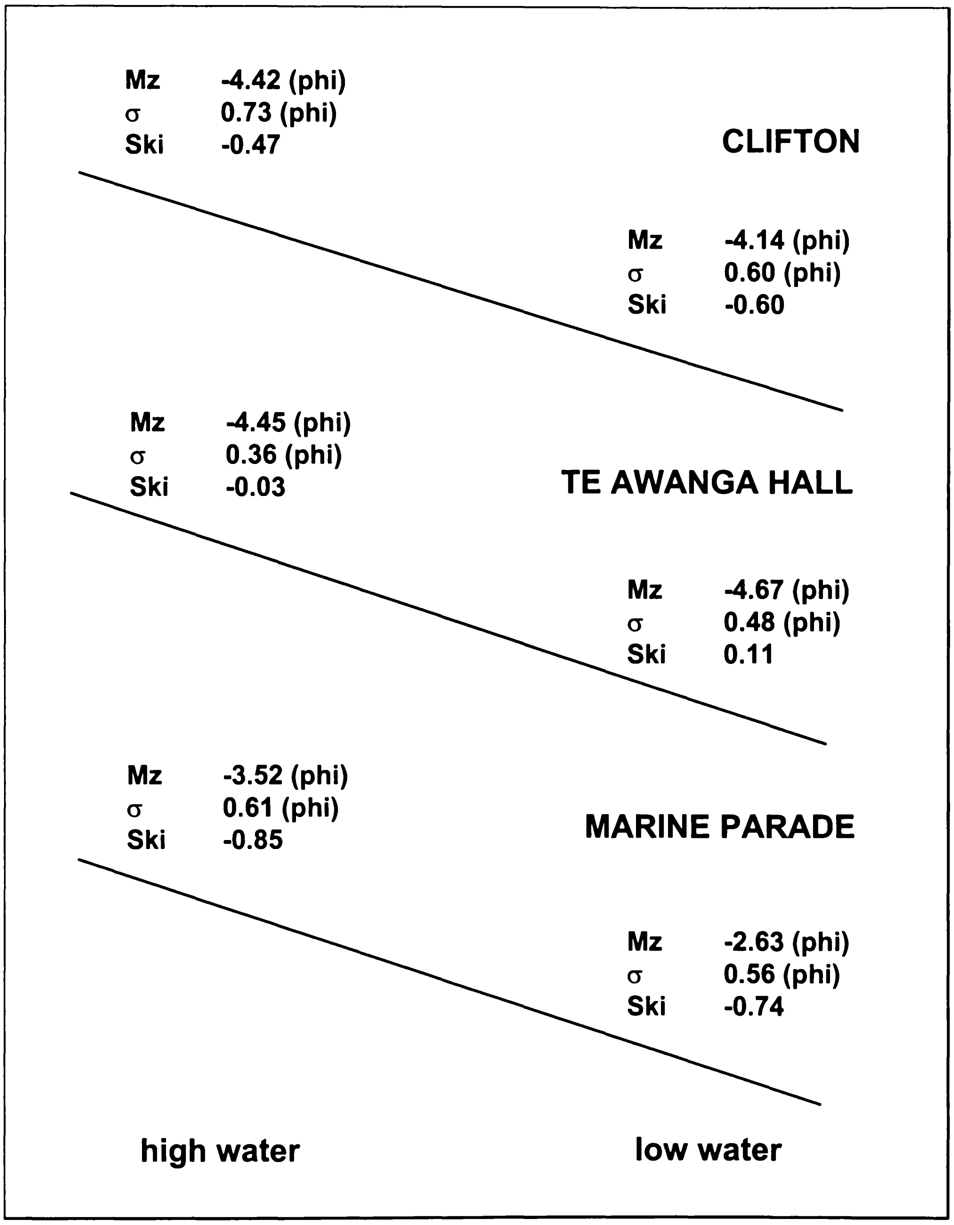


Figure 10.8 High and low water gravel size parameters, ***Mz*** *is mean grain size,* ***s*** *is sorting, and* ***Ski*** *is skewness (determined by moment measures). Relative positions on stylised profiles for the supply, (Clifton, Te Awanga) and the sink, (Marine Parade), 28 September 2000.*

The McLAREN model (McLAREN and BOWLES, 1985) suggests sediment size parameters can be in either a lag or a transport state with those in transport: -

i). C, B, +ve, (G)	high energy (winter), (G) (energy decrease), or
ii). F, B, -ve. (A)	low energy (summer) (A) (energy increase).

Accordingly, most HB sites are lag deposits, with the only exceptions as transport sediments are at the LW site, Clifton, and the HW site at Te Awanga Hall, both as a low energy (summer) state (A), energy increase sediment.

Some other observations can be made on the parameters: -

i). Not all sites become coarser at the HW sample site, and vise-versa the LW sites do not all become finer.

ii). HW sites generally more poorly sorted than LW sites.

iii). HW sites generally more negatively skewed than LW sites.

Cross-shore Supply and Sink.

Size parameters can be arranged in the cross-shore and alongshore directions for the supply (Clifton, Te Awanga) and sink (Marine Parade) and averaged.

	Supply	Sink
Mz (Phi)	-4.42	-3.07
s (Phi)	0.54	0.58
Ski	-0.25	-0.79

This arrangement of size parameters shows a surprising similarity of the averages where all environments fit into the verbal descriptive classes (ANDREWS, 1982; FOLK, 1968) large medium clasts, moderately well sorted and strongly coarse skewed. However, the Te Awanga Hall site is unusual as the sorting and skewness parameters are quite different from Clifton and Marine Parade. At Te Awanga Hall the sorting is better and the skewness more +ve than elsewhere.

Alongshore Supply and Sink.

		Mz(Phi)	σ(Phi)	Ski
HIGH WATER				
	SUPPLY	-4.44	0.54	-0.25
	SINK	-3.52	0.61	-0.85
LOW WATER				
	SUPPLY	-4.40	0.54	-0.24
	SINK	-2.63	0.56	-0.74

By classifying the parameters into a supply-sink and HW-LW arrangement and averaging the clast grain size parameters are: -

1). Clast mean grain size disparity occurs between the supply and sink and the HW and LW sites (relative sizes): -

supply	high and low water have small large sizes (these gravels are coarser)
the sink	high and low water gravels have large small, to small medium sizes (these gravels are finer).

2). Clast sorting on average has strong environmental similarity. Both supply and sink, and the high and low water have moderately well sorted gravels. However, if the Te Awanga Hall sample is omitted then the sink gravels have better sorting than the supply gravels.

3). Skewness has a disparity where the gravels at the supply high and low water are coarse skewed, whilst the sink high and low water clasts are strongly coarse skewed (where this is increasing -ve Ski towards the sink). Note the sink HW sample has the greatest negative skewness (-0.85) relative to all other samples.

10.3 Summary, Gravel Sizes and the Morphodynamic Responses to a Moderate Wave Energy Event.

The Textural Gravels.

1). According to the McLAREN model (McLAREN and BOWLES, 1985) the sediments at both the HW and LW sites are mostly lag deposits, except for the LW sample at Clifton that was in a winter transport state.

2). HB barrier MSG sediment responses to a moderate energy storm event are not similar. Of the three sites examined only at two of the sites do the gravel sizes at the HW run-up limit become relatively coarser in comparison to sediments at LW. These coarsening up beachface gravel sizes are Clifton (erosional) and Marine Parade. Marine Parade had recognisable gravel accumulation with a characteristic soft sediment substrate.

3). In the cross-shore up-beach direction gravels at the supply are coarser, more poorly sorted and more +ve skewed (approaching symmetrical) than the LW gravels and likewise at the sink gravels that are correspondingly coarser, poorer sorted and more -ve skewed (especially at the sink HW).

4) In the alongshore direction from supply to sink the mean grain sizes become finer, are more poorly sorted, and more -ve skewed. (state D) If Te Awanga Hall is excluded the gravels become finer, better sorted and are more –ve skewed (state A, a summer transport state, energy increase population). Te Awanga Hall demonstrates the local effect, where local ‘fluctuations’ can influence larger scale geographic trends.

The Morphodynamic Responses.

In late September 2000 a short period moderate energy event eroded an antecedent HW ridge. Three sample sites measure the morphodynamic changes that occurred at the HB barrier over this event. Sample sites are representative of the gravel supply (Clifton and Te Awanga) and sink (Marine Parade). At the supply sites the event was erosional, viz. sapping, whereas at the sink site the event was depositional as a veneer likely composed of material from the eroded HW ridge. These morphodynamic change measurements are the incident hydrodynamics (Iribarren number), beach profile slope (β) and the gravel samples from the HW and LW positions. The waxing wave steepness is (B_s before = 0.015; B_s during = 0.035) and spring tide, 1.8 m acting on beachface slopes.

The summary beachface slopes (averages) are: -

	Before	During	After
Supply	0.099	0.0929	0.0795
Sink	0.093	0.1025	0.087

As a morphodynamic parameter the Iribarren number changes are: -

	Before	During	After
Supply	2.656	1.058	1.259
Sink	2.486	1.168	1.377

Wave steepness and Iribarren number indicate the incident wave type was spilling, or plunger-spilling often associated with accretional (summer, accretional type, coarse sediment) HW ridge beaches, but in the HB the only accretion was Marine Parade, other sites were HW sapping, with the only common accretion taking place at Low Water.

Profiling between August and September shows an overtop event took place with gravel accumulation on the antecedent HW ridge. Beachfaces then remained stable until the time of the moderate wave energy, and the gravel sampling. As profile types the site classifications are: -

	At sampling time	After gravel sampling time
Supply		all sites, both sink and supply generally became concave up
Clifton	concave	
Te Awanga Hall	convex	
Sink		
Marine Parade	concave	

The cross-shore profiles can be related to the observed processes taking place as: -

	At sample time	After gravel sampling time
Supply		
Clifton		
	accretional step	erosional step
	erosion of HW ridge	platform accretion
		HW sap
Te Awanga Hall		
	accretional step	erosional step
	erosion of HW ridge	platform accretion
		HW sap
Sink		
Marine Parade		
	erosional step?	accretional step
	erosional HW ridge	platform accretion
	overtop deposition	HW sap

Profiles at the time of gravel sampling were representative of an active gravel transport, and the subsequent profiles generally suggest that both the supply and sink sites did not recover after the moderate event.

Gravels representing HW ridge sap and LW accretional proto-cusps were mostly lag deposits except for the Clifton LW sample being a transport state (sediment texture state (A) characterised by finer, better sorted, -ve skewness) representing a low energy summer state McLAREN type classification (McLAREN and BOWLES, 1985). The sites with HW coarser gravels were at Clifton and Marine Parade (with depositional soft substrates) and both of these sites had concave (erosional) profile types.

The average size parameter states were: -

Supply	coarser, better sorted (tending to well sorted), +ve skewness (state G) a winter transport, energy decrease state.
Sink	finer, poorer sorted, -ve skewness (state D) a lag state.

Both of these states correspond to the high energy Nash Beach, Wales, (BLUCK, 1967) and the supply sites have similar characteristics to those found by KIRK (1980) for long-term erosion beaches in the South Island. Within the high energy Nash Beach typology the HB supply parameter states correspond to the Nash Beach HW gravels, whilst the HB sink parameter states correspond the Nash Beach LW gravels.

The relative energy gradient alongshore for the HB is the supply sites have low energy and the sink sites high energy. BRYANT (1982) suggests sorting should improve (become well sorted) towards high energy, and HB gravels tend to be better sorted at the higher energy sink site, however

MOUTZOURIS (1991) found high energy zonal beaches to be coarser but in HB the high energy zonal gravels are finer. However, the 'supply' site Te Awanga Hall has better sorting and more +ve skewness. SONU (1972) suggests the Nags Head, North Carolina, sandy beach become finer grained, better sorted and have more -ve skewed as they become erosive. This would suggest that the supply sites are depositional and the sink is erosional.

10.4 Conclusions.

This chapter examines the event scale cross-shore relationships at three sites over a moderate energy event. The three sites are the supply (Clifton and Te Awanga Hall) and the sink (Marine Parade).

Over this moderate wave energy event, the HW ridges eroded by a process of wave run-up sapping and swash down combing to an accretional lower beachface platform with developing proto-cusps at all sites except Marine Parade. At Marine Parade the HW ridge eroded and at gravel sampling the beachface gravels were overtop deposits (reworked HW ridge). High seas prevented measurements of the Marine Parade profile to the step. At all sites, the accretional platform step later became erosional.

Supply beachface slopes decrease (β changes from 0.1 to 0.09) and sink slopes increase (β changes from 0.09 to 0.1) as wave steepness (B_s) increased from 0.019 to 0.035. Profile types appear well constrained between convex and convex-composite (or concave-composite).

All gravels were lag except Clifton LW where gravels correspond to a McLAREN (McLAREN and BOWLES, 1985) transport (summer) state. Comparing supply and sink gravel size parameters, the supply HW and LW gravels are coarser than the sink counterparts, specifically the supply gravel mean grain size is 'small large' sizes (Ave -4.42 Phi), and the sink gravel mean grain size is 'large small to small medium' sizes (Ave -3.07 Phi). Average sorting is near uniform (supply = 0.54 Phi; sink = 0.58 Phi). This is misleading since Te Awanga Hall gravels are well sorted, especially at HW. If the sites Clifton and Marine Parade are chosen, the sorting improves from the low energy Clifton to the high energy Marine Parade. Most sorting difference is at HW sites with the sink HW sample poorly sorted (0.61 Phi) and Clifton with the poorest sorting (0.73 Phi). Supply sites are relatively more +ve skewed at both HW and LW sites (Ave -0.24) than the sink (Ave -0.5), however, the sink HW site had the greatest skewness at HW (-0.85). The supply gravels (Clifton) are akin a McLAREN (McLAREN and BOWLES, 1985) lag (courser, poorer sorted and more + skewness (state B)) whilst the sink (Marine Parade) gravels (finer, better sorted and more negatively skewed (state (A)) is a summer transport, energy decrease state. This result for Clifton is a distinctive supply effect wth a variable supply of poorly sorted cliff fall material in a low energy environment. However, the well-sorted nature of the gravels at Te Awanga Hall could be the result of the improved sorting in a relatively short distance and a local greater energy wave environment.

CHAPTER 11 BEACHFACE RESPONSE TO A "HIGH SEAS" EVENT.

11.1 Introduction.

This Chapter examines the beachface gravel size parameters for a high 'storm' seas event that impacted the southern Hawke Bay coast in early June 2000. The high seas storm event was characterised by a gravel accumulation at the HW ridge at the Te Awanga Hall. This Chapter explores the gravel textural parameters associated with this HW ridge depositional event with an aim to explore the changes of the gravel textural parameters as they accrete at the HW ridge, firstly as overwash and later as overtop deposits, and the associated morphodynamics.

Sampling.

Southern Hawke Bay beachface morphodynamics are associated with high wave energy events that can be accretional. In this Chapter, the measurements of the beachface cross-shore transverse profile (beachface slope) and the breaking wave steepness are associated with the gravel textural parameters.

On two occasions, three samples were taken across an accretional HW ridge at fixed cross-shore distances. On the first occasion, on the 3 June 2000 the gravels represent an overwash deposit and on the second, on the 6 June 2000 an overtop deposit. Each sample site is spatially specific (Figure 11.4): -

S1	the most landward overwash sheet accumulate
S2	an overtop deposit at the HW ridge crest, and
S3	overtop, spring tide and HW run up.

This site developed a convex 'summer' profile as sediment deposited and accumulated at the antecedent HW ridge. The deposition is characterised by episodic overwash sedimentation on a HW ridge and finally overtop accretion on the seaward edge of the HW ridge. The antecedent HW ridge developed into a convex up 'summer' profile over a time period of some 10 days. The HW ridge comprised a series of transgressive gravel sheets and fines arranged as strata.

To recap, the high energy event in early June 2000 consisted of an incident breaking wave height (H_b) > 2.0 m and a greater than usual spring tide of 1.9 m.

A series of two photographs (Figures 11.1 and 11.2) over the June 2000 sampling period are down beach views from a point 28 m from a BM and show the general conditions.

The High Wave Energy Event.

After the formation of a HW ridge, subsequent waves on a waxing high spring tide transported gravels as overwash sheets (Figure 11.1). As the energy decreased the gravel transport and mode of deposition changed to overtop deposition on the crest of the HW ridge (Figure 11.2).

Figure 11.1 is Te Awanga Hall, 3 June 2000, 1110, low water 1158 and shows the conditions at the time of sampling the overwash gravels. The wave breaker is similar to 26 September 2000, (Chapter 10) as a trapped wave break. To seaward, the incident breaking wave crest is well inshore with a limited length of breaking crestal length. At the step, the wave breaker is a stalled wave-crest that can locally increase water depths so that the following incident wave can break as a surger further up the beachface. The breaking surger can produce jet flow across the steeper upper beachface, with associated projectile gravel transport through air, as a 'saltating' bedload. In the photograph the plunging length of the standing wave crest is above a cross-beach cusp horn, over which return flow has retarded and collapsed the stalled wave into a spiller with bore characteristics.

The breaking wave (Figure 11.2) is a standing trapped wave with two distinctive crestal breakers. First, there is surging over the cross-shore cusp horn (which is asymmetric with the horn tip displaced to the left), and second, as a standing spiller over the bay to the observers right.

(John White print 12)

*Figure 11.1. Te Awanga Hall, 3 June 2000. Sediment deposition and the High Water ridge morphology. **X** (' ") and **Y** (' ") are series of overwash gravel deposits forming depositional swash limit ridges. These swash limit ridges mark the landward limit of successive overwash sheets. The earliest sheet, the line **X' Y'** forms the southern edge of an overwash lobe and line **X Y** is a successive depositional lobe. The final deposition took place along the crest of the HW ridge along the line **X" Y"**.*

The cross-shore textures on the lower beachface, usually a plan bed, are sandy grits, especially the cross-shore horn, and in the adjacent bay. In the bay are large and medium sized gravels with many rolling towards the breaker zone. These rolling gravels are overpass gravels. Overpass gravels are a consequence of size selection as the swash and backwash shear stress differences selectively transport and deposit sands and gravels (ISLA, 1993). The gravels forming the HW ridge (Figure 10.2) are composed of large sizes infilled by very well sorted medium size gravels (and increasing fine +ve skewness) Deposition can be rapid, on occasion after a prolonged high swell, seaweeds can occur partially buried by successive gravel overtop-overwash deposits.

Note, the similarity of the position of the cross-beach cusp horn in both Figure 11.1 and 11.2.

In Figure 11.2 the sample bags are in situ, the closest to the observer is S2, and to seaward is sample S3.

Figure 11.2. Te Awanga Hall 6 June 2000, 1400, low water 1441. Post high wave energy event, and the second gravel sampling for the overtop gravels.

11.2 Results.

Data for this event are: -

1). Tides and incident wave characteristics. Wave steepness (B_s), wave breaking height (H_b), breaking wave period (T_b) (Figure 11.3).

2). Cross-shore transverse profiles for the Te Awanga Hall site, incorporating the before and after event profiles, Figures 11.4.

3). Gravel size parameters at the select sites across the accreting HW ridge (Figure 11.5).

Tides, Incident Waves and Morphodynamics.

Over the sampling period the tidal levels (NAUTICAL ALMANAC, 1999) cycled from a long period neap tide ranging 0.2 to 1.5 m over 14 days to 30 May 2000. This was followed by a rapid rise spring (31 May, ranging 0.2 to 1.6 m, and on 2 June ranging 0.1 to 1.8 m).

The effective atmospheric conditions over this sampling period began on 24 May with a rapid increase of the atmospheric pressure and an increasing and rapidly fluctuating wave breaker height and period (Figure 11.3). The beachface morphology underwent rapid changes as surficial sediments adjusted to the fluctuating energy, notably the formation of cross-swash cusps (cusp horn spacing (Cs) 28 m). On 29 May 2000, the atmospheric pressure began to rapidly drop and a warm front passed south across HB.

Wave height began to increase on 27 May and high tide run-up limit increased to landward, reaching a maximum at 25 m seaward from the BM on the 31 May 2000. Usually high tide is some 40 m from the BM. As the waves increased the gravels began to transport to both landward and seaward, with landward gravels saltating up the beachface (ranging in size from large to medium gravel) to accumulate at and form a HW ridge over the period 31 May to 2 June. At high tide the broken wave run-up mobilised the beachface and lobes of gravels overwashed (Figure 11.1) infilling the 'runnel' landward of the accumulating HW ridge until 3 June 2000.

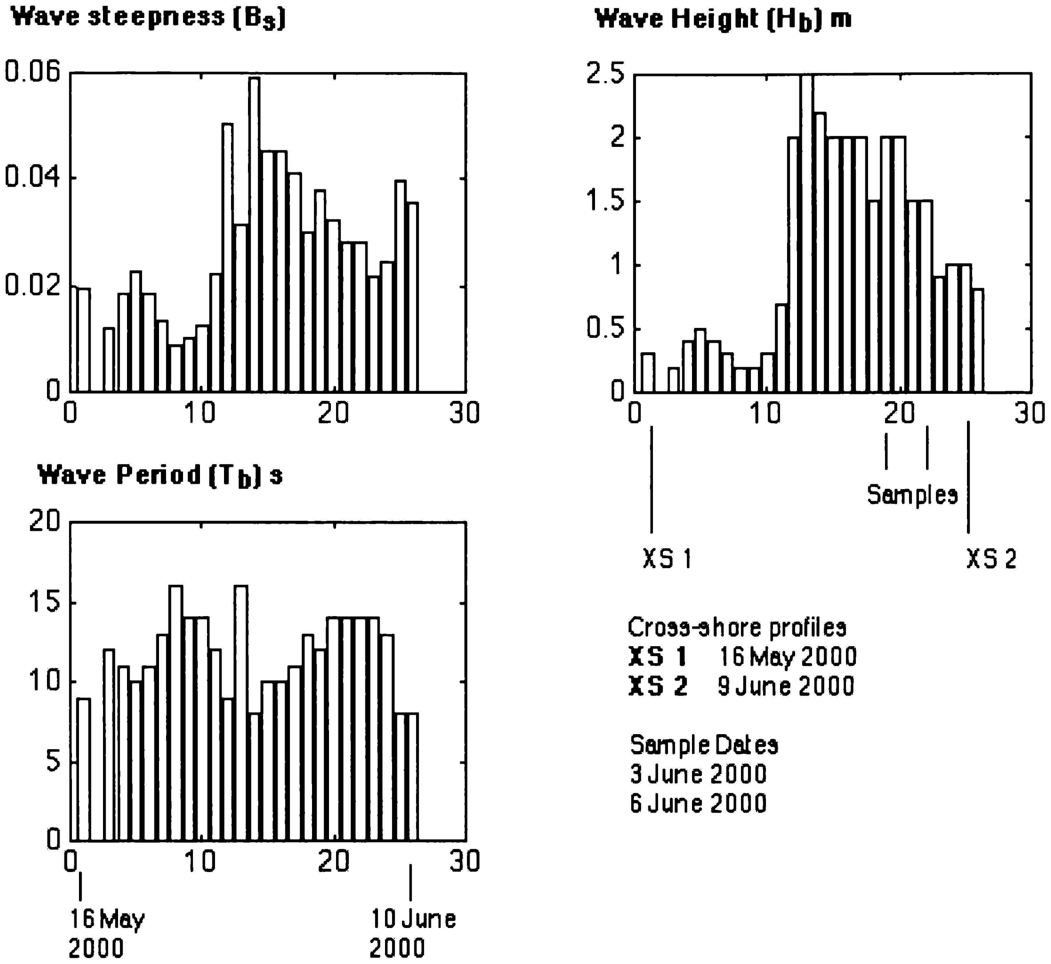


Figure 11.3 High wave energy event wave parameters for the period 16 May 2000 to 10 June 2000. The averages over this data period are wave steepness (B_s) 0. 28, wave height (H_b) 1.14 m, and period (T_b) 11.84 s. The duration of this high-energy event was some 8 days when wave height (H_b) ≥ 2.0 m and the wave steepness (B_s) > 0.04 for some 5 days.

Atmospheric pressure began to increase on 3 June, and the high tide run-up limit decreased to further down the beachface. Gravels continued to saltate up the beachface and deposition took place along the crest of the HW ridge as overtop deposits (Figure 11.2). Further deposition on the seaward face of the HW ridge effectively increased the HW ridge width. The beachface slope and wave steepness for a GALVIN type plot (ORFORD, 1977, Figure 6, p 391; see Chapter 12) were: -

Cross Section Date	Beachface slope	Wave steepness
16 May	0.1008	0.0194
9 June	0.0978	0.0399

and, on the gravel sampling days: -

Gravel Sampling Date	Wave steepness	Iribarren Number
3 June	0.0376	1.029
6 June	0.0279	1.398

To resolve the Iribarren number (BATTJES, 1974) it was assumed the beachface slope did not change significantly from 0.09.

The HW ridge early overwash gravel deposition wave steepness on 1 June 2000 was $B_s = 0.0451$ and the Iribarren number, $\xi = 0.796$.

Putting the HB beachface slope and wave steepness onto a GALVIN bivariate plot (ORFORD, 1977, Figure 6, p 391), the wave types show a shift from surging to plunger breakers, and a shift to ORFORD's 'step' or summer type profile (for Llanrhystyd, Wales, 13 October 1973). Thus, when the HB gravels transported and deposited as overwash lobes the wave breakers were surging waves. ORFORD (1977) and ORFORD and CARTER (1985) suggest the wave breaker types for MSG beach crest and overwash sedimentation are spillers, although the summer step (HW swash ridge) beach Llanrhystyd, 13 October 1973 wave breaker types inclined towards surgers.

Cross-shore Transverse Profiles.

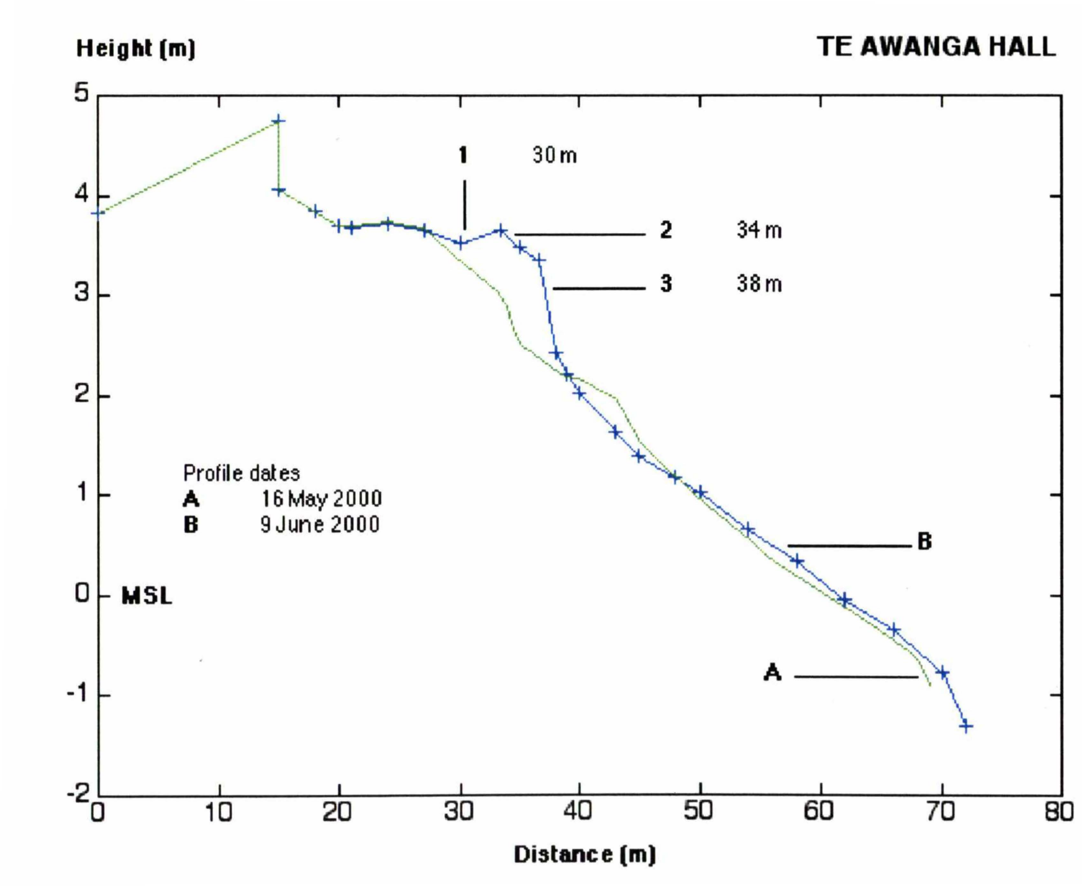


Figure 11.4 Te Awanga Hall HW ridge accretion event. A high-energy, spring tide, beachface accretional MSG overwash and overtop. The cross-shore transverse profiles (before May 2000, and after 9 June 2000) and the gravel sample sites (cross-shore distances from BM parentheses), May-June 2000.

Two cross-shore transverse profiles define the changes to the beachface morphology (Figure 10.4). The initial 16 May profile remained 'stable', since from mid May the tidal water level was in a neap phase and the breaking wave heights generally small (Figure 11.3), therefore, there was small beachface sediment volume change.

After surveying the Te Awanga Hall beach on 25 September 2000, in the pockets of the shorts (sediment traps) the sediment textures were bimodal with gravels 2 mm to 4 mm, well rounded and angular, and very fine sands. These sediments are representative of the transport population in the wave turbulent water column.

The Gravel Sizes.

Figure 11.5 summarises the gravel size parameters and their relationship to the accretional morphology. In the up beachface cross-shore direction (sample sites S3 to S1) the
verbal descriptive (ANDREWS, 1982; FOLK, 1968) gravel size parameter changes over the depositional period are: -

3 June 2000. Overwash depositional gravels become coarser, better sorted and increasingly +ve skewed to landward (S1).

6 June 2000. Subsequent overtop depositional gravels become finer, better sorted and increasingly -ve skewed at S1.

Within this general descriptive, there are important variations, about the ridge crestal location, for example,

1). On 3 June size the parameters at site S2 had mid-range sorting and skewness values, when compared to the adjacent S1 and S3. The most poorly sorted and –ve skewed gravels are to seaward (S3).

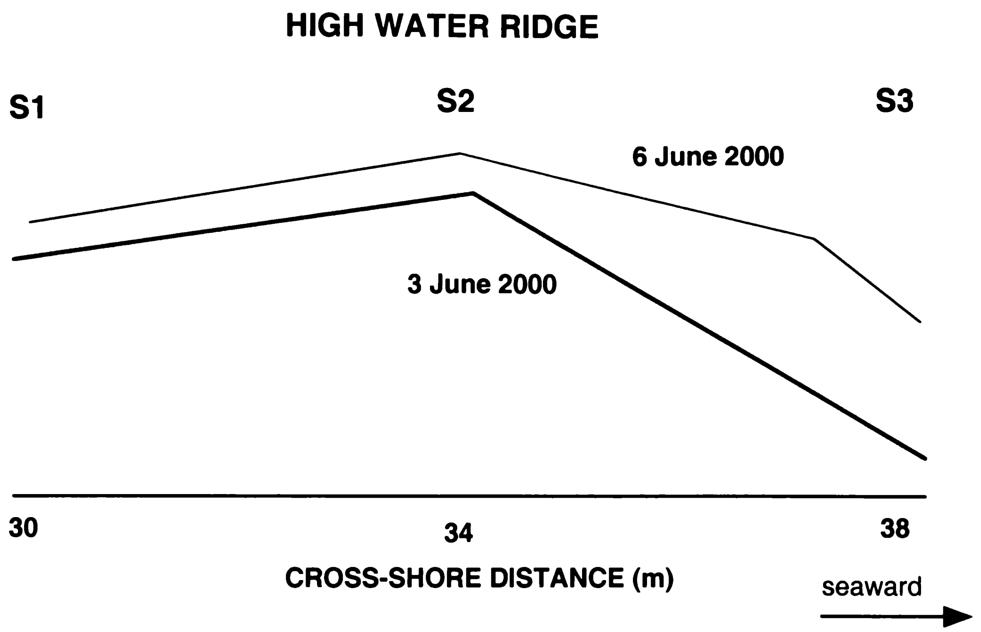
2). On 6 June the HW ridge crest gravels at S2 were finer, better sorted and more +ve skewed than the adjacent samples (S1 too landward and S3 too seaward).

Placing these parameters into a McLAREN type model (McLAREN and BOWLES, 1985) in an up beachface transport and depositional direction we have the following states: -

	McLAREN MODEL (state)		
Date	S1	S2	S3
3 June 2000	C, B, +ve (G)	C, B, +ve (G)	F, P, -ve (D)
6 June 2000	C, P, -ve (E)	F, B, +ve (F)	C, P, -ve (E)

Placing these into a McLAREN (McLAREN and BOWLES, 1985) transport type sediment facies,

3 June (S1 and S2)	C, B, +ve (G)	high energy winter transport state
6 June (S2)	F, B, +ve (F)	a lag state.



SAMPLE SITES S1		S2		S3	
6 June 2000					
Mz	-4.84 (phi)	Mz	-4.76 (phi)	Mz	-5.31 (phi)
σ	0.39 (phi)	σ	0.35 (phi)	σ	0.50 (phi)
Ski	-0.44	Ski	+0.23	Ski	+0.09
3 June 2000					
Mz	-4.54 (phi)	Mz	-4.55 (phi)	Mz	-2.95 (phi)
σ	0.44 (phi)	σ	0.58 (phi)	σ	0.61 (phi)
Ski	+0.22	Ski	-0.36	Ski	-0.64

Figure 11.5 Te Awanga Hall. Gravel size parameters for an accretional event at a high water ridge, from 3 June to 6 June 2000.

11.3. Discussion Grain Size Parameters.

The cross-shore selective gravel size sorting and relationships with the geomorphology are well recognised in the field (BLUCK, 1967; SHERMAN, ORFORD and CARTER, 1993). SHERMAN, ORFORD and CARTER (1993) described tiered cusp horn sediments as coarser and better sorted towards the upper beachface when compared to their companion lower beachface cusp horns. BLUCK (1967) notes the high-energy storm beach state at Newton, Wales, can have beachface zone associated gravely sizes as: -

1). Upper beachface, coarse gravels, well-sorted, symmetric skewness.

2). Lower beachface, finer gravels, poorer sorting, more -ve skewness.

The Te Awanga Hall state on 3 June is similar to the Newton Beach upper beachface with coarser gravels, better sorted and a near symmetric skewness between the HW ridge crest and overwash gravels; but, on 6 June any similarity has vanished, with the exception of sorting which maintains an up beachface well sorted trend towards well sorted.

WILLIAMS and CALDWELL (1988) suggest at a high energy Welsh beach, storm conditions combined with a high tide, the gravel population can have: -

1). Slight differences at the HW accretional ridge in accumulating and erosional phases, with no overall change in size (or shape).

2). Across-beach the size shape sorting may be more important in some beachface zones than others.

McKAY and TERICH (1992) sampled the Washington State MSG barrier at three cross-shore sites corresponding to LW, HW and crest. Gravel sampling took place in summer and winter seasons with corresponding measurements of the wave and cross-shore profile characteristics. The highest waves occur in winter (winter, December, mean monthly significant wave height $H_s = 4.3$ m; summer, August, $H_s = 1.5$ m). The cross-shore profiles have summer convex up and winter concave up profiles. The Washington barrier experiences both overtop and overwash morphodynamic processes.

McKAY and TERICH (1992) found the winter gravel sizes increase at both the low and high water sites and less so at the crest. The gravel sorting tends to be better in winters and sorting is generally better at the crest than at HW, and especially at LW sites that tend to be the most poorly sorted of the three cross-shore sample sites.

The Washington State winter samples are the likely overtop and overwash process representatives, especially those at both HW and crest respectively. Overtop gravels could be finer, and overwash gravels coarser and both better sorted than the LW finer and more poorly sorted gravels.

CARTER and ORFORD (1981) sampled the sediments across an overwash lobate deposit on a MSG barrier in southeastern Ireland. This Carnsore Point transgressive overwash sediment passed through a throat (ORFORD and CARTER, 1982) possibly as a storm event sheet. CARTER and ORFORD (1981) recognise a succession of processes that includes up beachface coarse gravel transport and the formation of a ramp leading to the beach crest throat. Overwash sediments transport up the ramp and through the throat to form lobate fan sheets to landward of the beach crest.

At Carnsore Point the gravel size parameters passing landward with the overwash are: -

Size Parameter	On Beach	Throat	Overwash
Mz (Phi)	-2.9	-2.8	-3.3
sort coeff	1.2	1.0	0.8.

The Te Awanga overwash, 3 June 2000, has similarity to Carnsore with a coarsening and better sorting of gravels to landward. The Te Awanga 6 June, overtop deposition is a complete opposite to Carnsore storm deposition where the Te Awanga overtop deposit has marginally finer grain sizes and better sorting than samples to either seaward, or landward.

Also the Te Awanga gravel skewness changes from an overwash becoming increasingly more +ve to landward to an overtop deposit that becomes more -ve landward, (where the later is a fill).

From these results, it appears that landward transgressive gravels are coarser, better sorted and more +ve skewed than the Carnsore Point beachface (seaward) companion gravels of CARTER and ORFORD (1981).

SONU (1972) describes the sediment size parameters at cross-shore sites as a swash bar migrates landward. SONU (1972) proposed swell waves shift coarse grains landwards in conjunction with a bar morphology migration landwards and the cross-shore profile becomes more convex up. The emergent bar composed of coarse material has a single mode (well sorted) and has +ve skewness. SONU (1972) suggests the relationship between sediment texture and morphodynamic processes occur over a period of time. The process starts where the coarse material allows rapid percolation of successive waves and any saltating finer material traps as fill in pores between the previous coarse material deposits. The result of continued sediment accumulation is an increasing topographic ridge height.

Similarity with the HB HW ridge site. The initial overwash sediments have better sorting and have +ve skewness and later become more poorly sorted and –ve skewed. Correspondingly, the skewness becomes more symmetric as the trapped fines increase and the site sediments become increasingly bimodal. As the fines continue to fill the bulk sediment skewness becomes increasingly +ve, for example in HB sites S2 and S3.

Therefore, the McLAREN model (McLAREN and BOWLES, 1985) shows the facies for the Te Awanga Hall overwash are a winter transport, energy decrease state facies (C, B, +ve (G)) and the overtop are a lag state (F, B, +ve (F)).

11.4 Summary, The Morphodynamic Responses to a High Wave Energy Event.

During a high seas event, an accretionary HW ridge formed on the Te Awanga Hall beachface. This HW ridge was subsequently overwashed as tidal water levels approached a maximum spring tide and as the high seas continued. Later over top deposition occurred on the HW ridge.

Over this event the beachface slope decreased (0.10 to 0.09) as wave steepness increased (0.019 to 0.037) with a co-relationship Iribarren number, ξ = 1.029. At the height of the event on 1 June the wave steepness (B_s) was 0.0451 and Iribarren number, ξ = 0.796. The morphodynamic responses to the beach included an energetic HW ridge overwash and overtop accretion accompanied by accretion at the lower beachface platform and step. These accretions changed the cross-shore profile shape from a HW ridge convex summer type to a HW ridge concave-composite winter type.

As the tidal water level reduced and the high seas abated the gravels in transport at the high water swash accumulated as overtop gravels on the HW ridge crest. These landward transporting gravels have well-defined size parameters in the landward direction where the overwash sheet mean grain sizes become coarser, the sorting better, and skewness increasingly +ve. Overtop gravels had better sorting and increased +ve skewness compared to samples to either landward, or seaward.

11.5 Conclusions.

A HW ridge accumulated via overwash and later overtop sediment transport. The beachface slope flattened (from an initial $\beta > 0.1$ to $\beta = 0.09$), with an increasing breaking wave steepness (B_s 0.019 to 0.037). Gravels transported landwards as overwash with $B_s = 0.0451$; Iribarren number $\xi = 0.796$. Gravels tended to become coarser (-4.54 Phi), better sorted (0.44 Phi) and increasingly +ve skewed (+0.22). Later in the deposition sequence ($B_s = 0.0279$; Iribarren number $\xi = 1.398$) the overtop gravels were coarser, had improved sorting (0.39 Phi) and -ve skewness (-0.44). Overtop gravels that welded onto the seaward face of the HW ridge, the seaward overtop population, were coarser, better sorted and had +ve skewness (relative to the previous overwash population). Hence, the overwash sediment facies equates to a McLAREN (McLAREN and BOWLES, 1985) transport, energy decrease winter state (G) facies. The overtop gravel facies was split into a landward lag, state C deposit and the seaward overtop population was a winter, energy decrease transport facies G.

CHAPTER 12 THE RESPONSES OF THE COMBINED MODERATE AND HIGH WAVE EVENTS AT TE AWANGA HALL.

12.1 Introduction.

The Te Awanga Hall beachface slope (β) and the breaking wave steepness (B_s) parameters for the early June 2000 (high energy) and the late September 2000 (moderate energy) events are placed onto a GALVIN plot (ORFORD, 1977; Figure 6, p 391) to determine the relationships between these parameters and the breaker types associated with these morphodynamic events. From these events, it is possible to locate a critical breaking wave steepness below which accretion can take place, and above which the beachface erodes.

12.2 Results and Discussion.

Figure 12.1 shows the bivariate relationship between the Te Awanga beachface slope and the breaking wave steepness, and superimposed upon the graph are the wave breaker types. As a general comparison between ORFORD (1977, Figure 9) and Te Awanga Hall the Te Awanga Hall beachface slopes are slightly flatter and the breaking wave steepness less than ORFORD (1977).

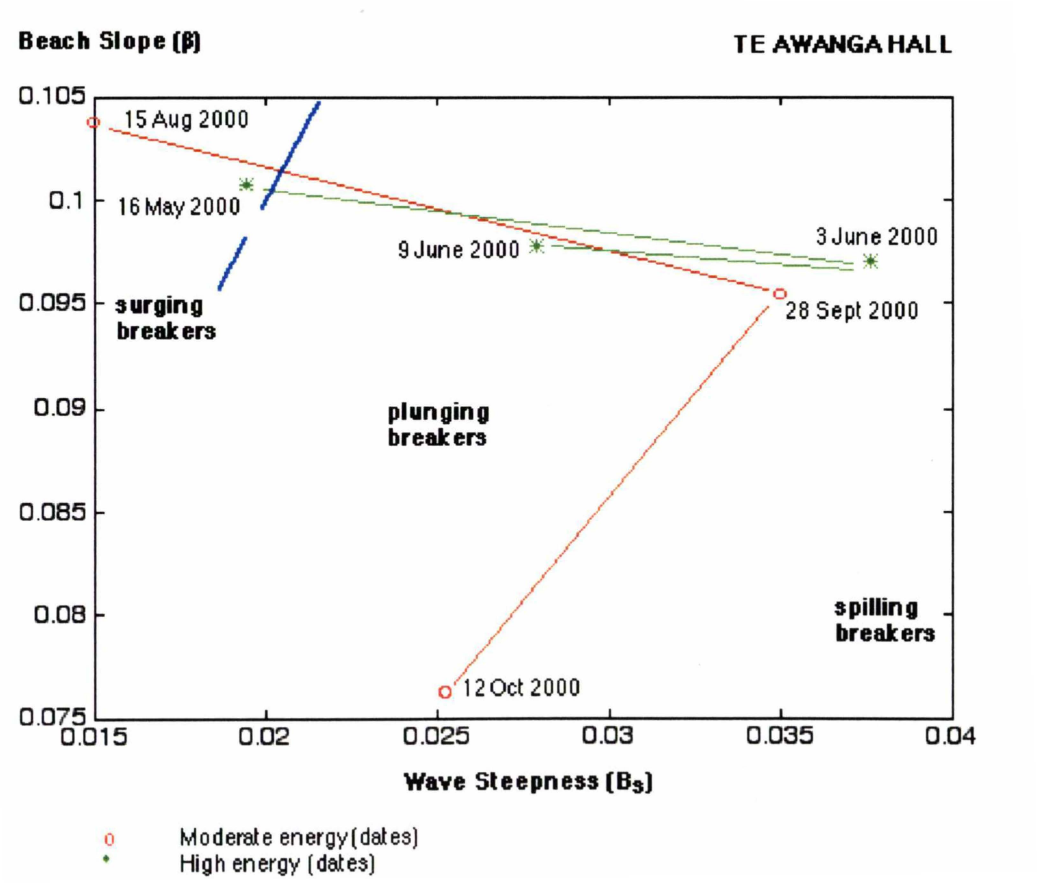


Figure 12.1. The Te Awanga Hall beachface morphodynamics, for moderate and high-energy events. The relationship between the beachface slope (β) and breaker steepness (B_s) for Te Awanga Hall data. The breaker types (after GALVIN) are also indicated. Note, firstly the spilling type are thought to initiate at $B_s > 0.04$. Secondly, there is also a collapsing wave type between the plunging and surging wave types.

ORFORD (1977) suggests for natural gravel beaches the B_s ranges from 0.02 to 0.03 as they change from a summer HW ridge (accretional) to a winter bar profile (erosional) type. Te Awanga Hall wave steepness (B_s) parameters straddle these values (Figure 12.1) where the low B_s ($B_s < 0.02$) associates with the steep (greater than 0.1) 'accretional' beachface. As B_s exceeds 0.03, the beachface slope flattens (β less than 0.1) to an 'erosional' type.

Whilst the energetic events are both characterised by $B_s > 0.03$ the morphodynamic responses of the beachface at the HW ridge are different with either an erosional sapping, or an accretional overwash (with accretional events having marginally greater B_s and β than the corresponding sapping type). At Low Water, the beachface is accretional at the lower beachface platform for both energetic events.

As the B_s value decreases (less than 0.03) the Te Awanga beachface slope becomes either flatter where the erosive beachface slope decreases (12 October 2000), or the slope can increase when the beachface HW ridge is accretional (9 June 2000 on Figure 12.1).

ORFORD's (1977; Figures 5 and 7) beachface slopes also flatten measured at the tidal (time) scale, and this could be likely as HUGHES and COWELL (1987) have demonstrated for reflective beaches in Australia. On the receding tide the HW sediments can downcombe and accrete at the step. The accretion at the step relates to an increase of the beach width making the beachface profile flatter

The wave breaker types change as the energetics increase with a shift away from surging towards spilling, at both Te Awanga and, at a tidal scale, Llanrhystyd Beach, Wales, (ORFORD 1977). At Te Awanga the profile type is initially convex-up and a HW ridge (summer) type and with increasing B_s the profile becomes concave up. This concavity compares to ORFORD's (1977) bar (winter) type profile, however, the Welsh beaches had greater wave steepness and a flatter beachface slope than the Te Awanga Hall beachface. The Te Awanga Hall profile types match ORFORD's (1977; Figure 9) step (ORFORD's 'step' is a HW ridge) profile type and fall within the summer profile type. ORFORD (1977, Figure 5) introduces a composite profile type with accretion at both the HW ridge and at the lower beachface intertidal zone. Therefore, the HB Te Awanga Hall beachface with accretion at both the HW ridge and the LW platform is closer to ORFORD's (1977) composite profile type.

The HB gravel samples associated with both moderate and high-energy events have similarities and differences. For both events, the HW ridge gravel samples become better sorted. The overtop gravels are very well sorted and fill a previously coarser overwash gravel. The differences appear to be gravel size related where the HW ridge accretion gravels are coarser and the erosional HW ridge sap gravels are finer. That the sap gravels are finer suggests the coarse sizes are not present on the antecedent HW ridge, or they move rapidly by avalanche inertia and overpassing in the swash. Indeed, at Te Awanga in September the gravels at LW are coarser and poorly sorted. Using the McLAREN model (McLAREN and BOWLES, 1985) the gravels at the run-up limit of deposition are either overwash or overtop and are winter transport state (G) sediments.

12.3 Conclusions.

Over two increasing energy events the breaking wave type changes have similarity where the breaker type changes from surging into plunging (and towards spilling).

Profile types are usually linear summer types at low value wave steepness. As the wave steepness increases so the profiles change. For example, with a moderate wave energy the profiles sap to become concave-up. With increasing wave energy, the profile can become convex-composite types (with accretion at both the profile HW and LW). The high-energy event accompanied an overwash and overtop accretional sediment facies at the HW ridge.

The Te Awanga Hall beachface slopes appear to have similar response for energetic seas events, where both the moderate and the high-energy events produce flatter beachface slopes. Beach profile types are somewhat more complex with no clear differentiation between convex up accretion summer types and winter concave up erosion types. Te Awanga Hall profile development depends upon the antecedent profile, but generally, the HW ridge sap would eventually produce a concave up profile as the HW ridge eroded. However, in these measured energetic events the profile can dimensionally increase so that the profile type becomes a concave-composite type profile with accretion at both the HW ridge and the LW platform (proto-cusp).

Generally, the Iribarren numbers (ξ) varies from low energy, stable conditions value of say 2.5, to a high seas value around 0.8. The Hawke Bay supply and sink beaches are mostly reflective types, $\xi < 1.12$, but can become transitional reflective-dissipative types in periods of stability and prolonged low wave height breakers. The Iribarren number places the wave breaker as mostly surging-collapsing (stable beach $\xi > 2.0$) and as energy increases the wave breaker becomes plunging and progressively closer to spilling, translating towards $\xi < 0.4$. At Te Awanga Hall, both moderate and high-energy events have Iribarren numbers showing similar progressions (Figure 12.1). Initial Iribarren numbers are approximately $\xi = 2.188$, as the events take place $\xi = 1.07$, and on recovery (12 October 2000) $\xi = 1.181$.

At gravel sampling, (Chapters 10 and 11) the beachfaces slopes were steeper at the supply sites (Clifton and Te Awanga Hall) compared to those at the sink site (Marine Parade). During events, the supply beachface slopes decreased whereas the sink beachface slope increased.

All gravel samples (Chapter 10, the HW and LW samples) group into the textural parameter classes, small to cobble sizes, well to moderately well sorted (with slightly better sorting at the sink and have a skewness progression with the supply gravels coarse skewed and the sink strongly coarse skewed. Hence, the gravels have increasing -ve skewness from the supply to the sink, along an energy gradient ranging from low (supply) to high (sink).

At an event scale not all beachfaces (supply and sink) respond in a similar fashion for a given event. Gravel sizes can become either coarser or finer at the HW and it is possible much depends on the antecedent morphology. For example, at the Te Awanga Hall, (Chapter 11) generally the gravely deposits at the HW overwash are coarse and the overtop deposits can be coarser. These overwash sediments are a winter transport state (G) in the McLAREN and BOWLES (1985) model.

Generally, the morphodynamic equations appear to describe the responses of the beachface over high wave energy events. From Figure 12.1 as a first approximation the Hawke Bay beachface (specifically the Te Awanga Hall beachface) can erode with a breaking wave steepness (B_s) greater than 0.026, and can accrete when $B_s < 0.026$.

CHAPTER 13 THE CLAST FORMS AT THE SOUTHERN HAWKE BAY BEACHFACE.

13.1 Introduction.

This chapter examines the textural gravel forms of the southern HB beachface firstly over a spring equinox (Chapter 9), and, secondly in the cross-shore direction associated with incident wave energy (Chapters 10 and 11). Gravel forms are derivatives of the orthogonal measurements of a clast following the methods of KRUMBEIN (1941). The clast forms, are blades, discs, rods and spheres (ZINGG, 1935; cited BARRETT, 1980); maximum projection sphericity (MPS) (SNEED and FOLK, 1958) and the oblate-prolate index (OPI) (DOBKINS and FOLK, 1970).

This Chapter aims to investigate the dispersion of the gravel clast forms at the southern HB MSG beachface, where: -

1). The temporal (seasonal) trend of the gravel clast forms over a sampling period at four sites. The sites are Clifton, Te Awanga Hall, Haumoana, and Marine Parade.

2). The longshore temporal clast form changes. The averaged synchronous sampling set of clast forms at each site (synchronous sampling on five occasions at four alongshore sample sites).

3). The relative clast form sizes at the supply (Clifton) and sink (Marine Parade).

4). The temporal (seasonal) trend of the OPI and MPS forms.

5). The average OPI and MPS (based upon seasonal data) for each site and the alongshore energy gradient relationships.

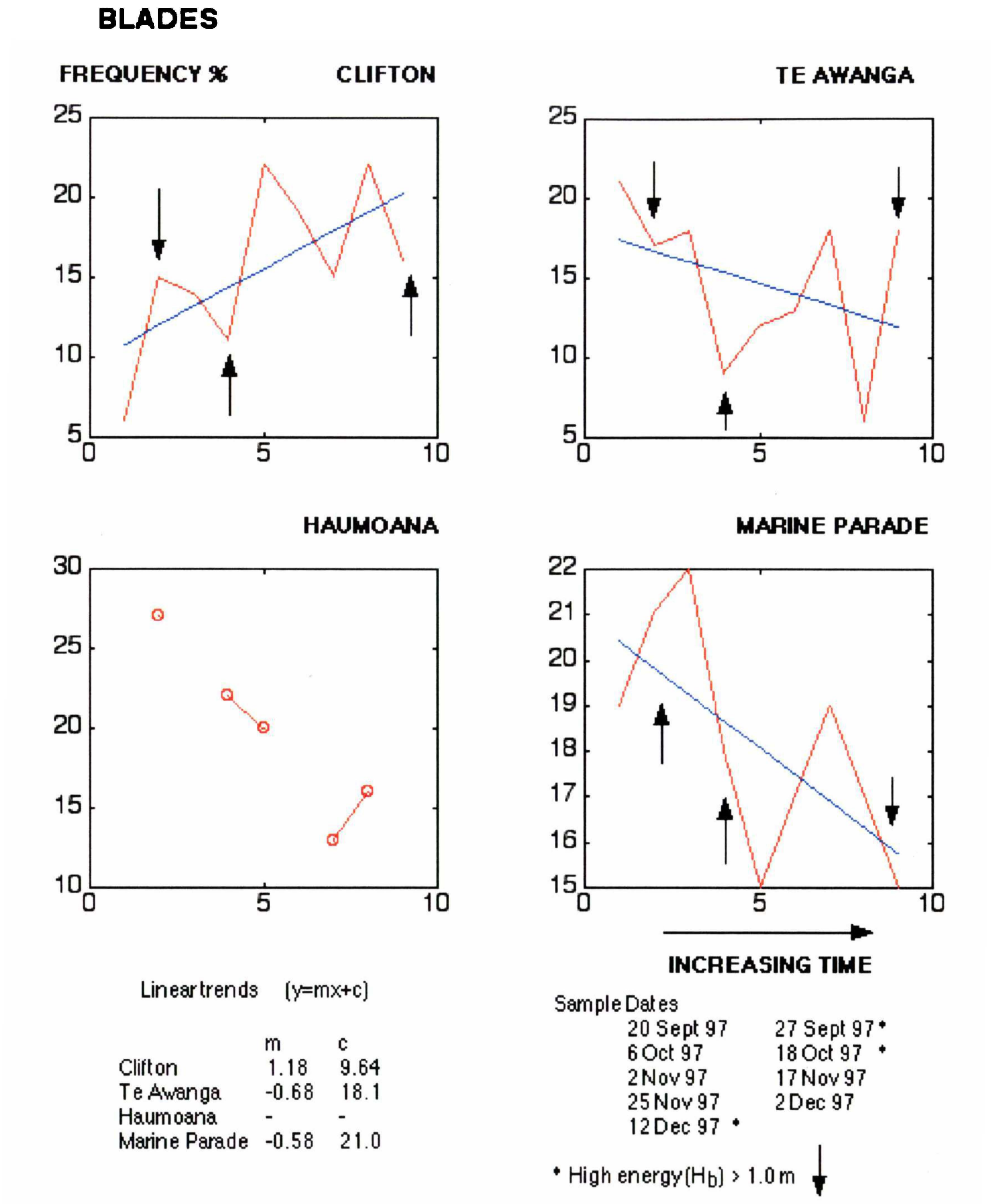
6). The responses of clast forms to dynamic processes where these are the moderate and the high wave energy events of Chapters 10 and 11.

13.2 Results.

At four synchronous sampling sites, as a temporal (seasonal) trend, the forms blades (Figure 13.1); discs (Figure 13.2); rods (Figure 13.3), and spheres (Figure 13.4) follow. Over the sampling period three high-energy events occurred, identified by '*' on each Figure. Appendix 6 has a summary of the breaking wave characteristics Note the clast data is split into two groups. The first group relates to the data from September to December 1997. In this Chapter, the September to December data are referred to as the long trend data. In Appendix 7, the second group is presented as a series of figures whose data extends from September 1997 to April 1998 and is used for comparison, for example to determine the possible seasonal signature of a clast form.

Blades. (Figure 13.1): -

Over the sampling period the blades decreased at all sites except Clifton, where they increased some 10%. At Haumoana, the blades decreased overall by some 15%. The remaining sites have small decrease percentage changes, with Marine Parade the lowest at some 5%.



	m	c
Clifton	1.18	9.64
Te Awanga	-0.68	18.1
Haumoana	-	-
Marine Parade	-0.58	21.0

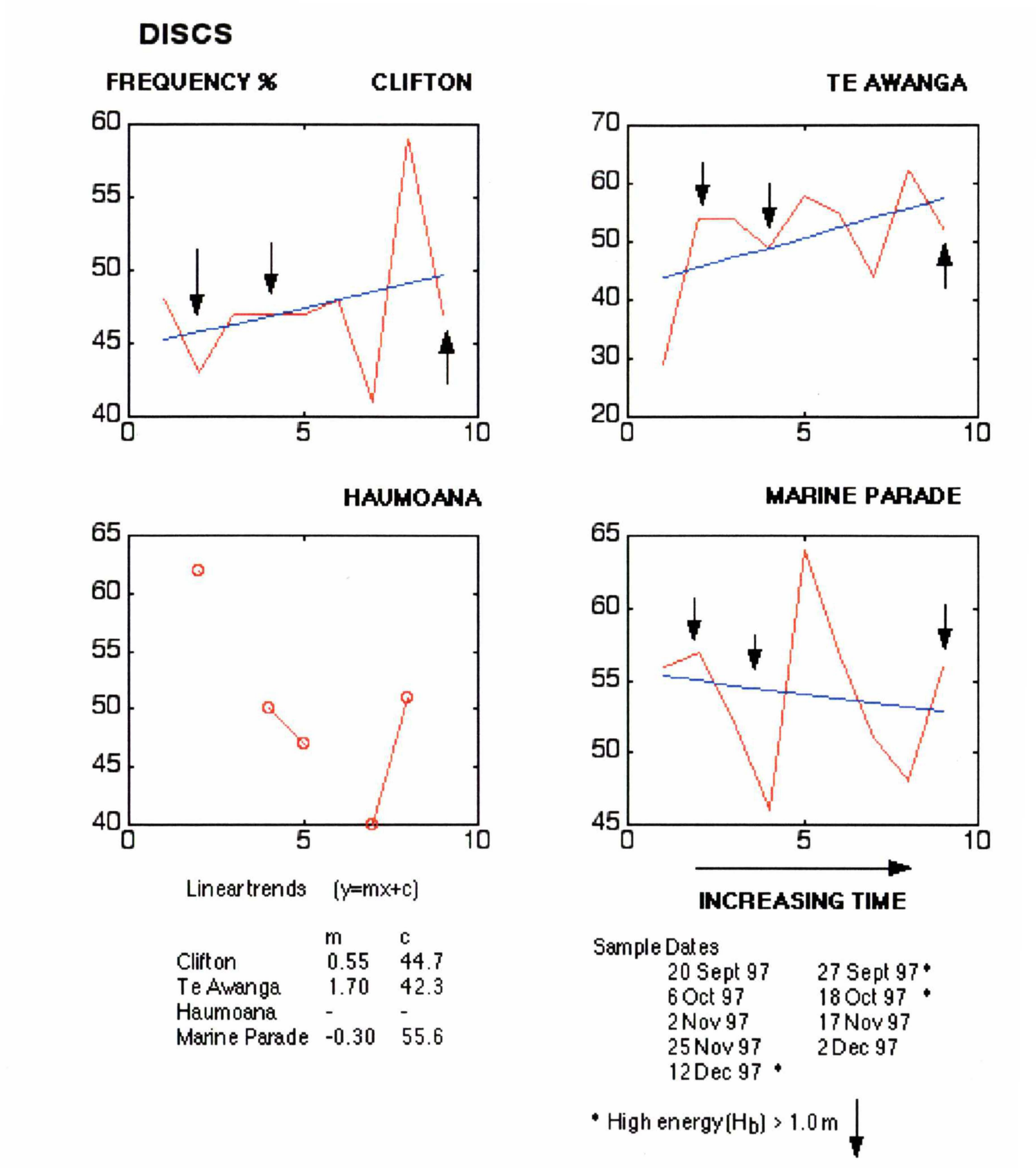
Figure 13.1. The bladed clast forms over the sampling period 20 September 1997 to 12 December 1997. The sampling period trends are for decreasing bladed forms, except for Clifton.

The magnitudes of the bladed variation are Marine Parade has low magnitude (a narrow range of bladed forms (6%)), and Clifton (16%), Te Awanga (15%) and Haumoana (14%).

Intersample trends either fluctuate or are continuous. A fluctuating sequence example is Te Awanga from 20 September to 2 November; Te Awanga also has a continuous sequence from18 October to 25 November. Marine Parade has a steady oscillation about a two-sample period.

Discs.(Figure 13.2): -

The long trend of the disc forms was to increase at Clifton, and Te Awanga,



Linear trends (y=mx+c)

	m	c
Clifton	0.55	44.7
Te Awanga	1.70	42.3
Haumoana	-	-
Marine Parade	-0.30	55.6

Sample Dates

20 Sept 97	27 Sept 97 *
6 Oct 97	18 Oct 97 *
2 Nov 97	17 Nov 97
25 Nov 97	2 Dec 97
12 Dec 97 *	

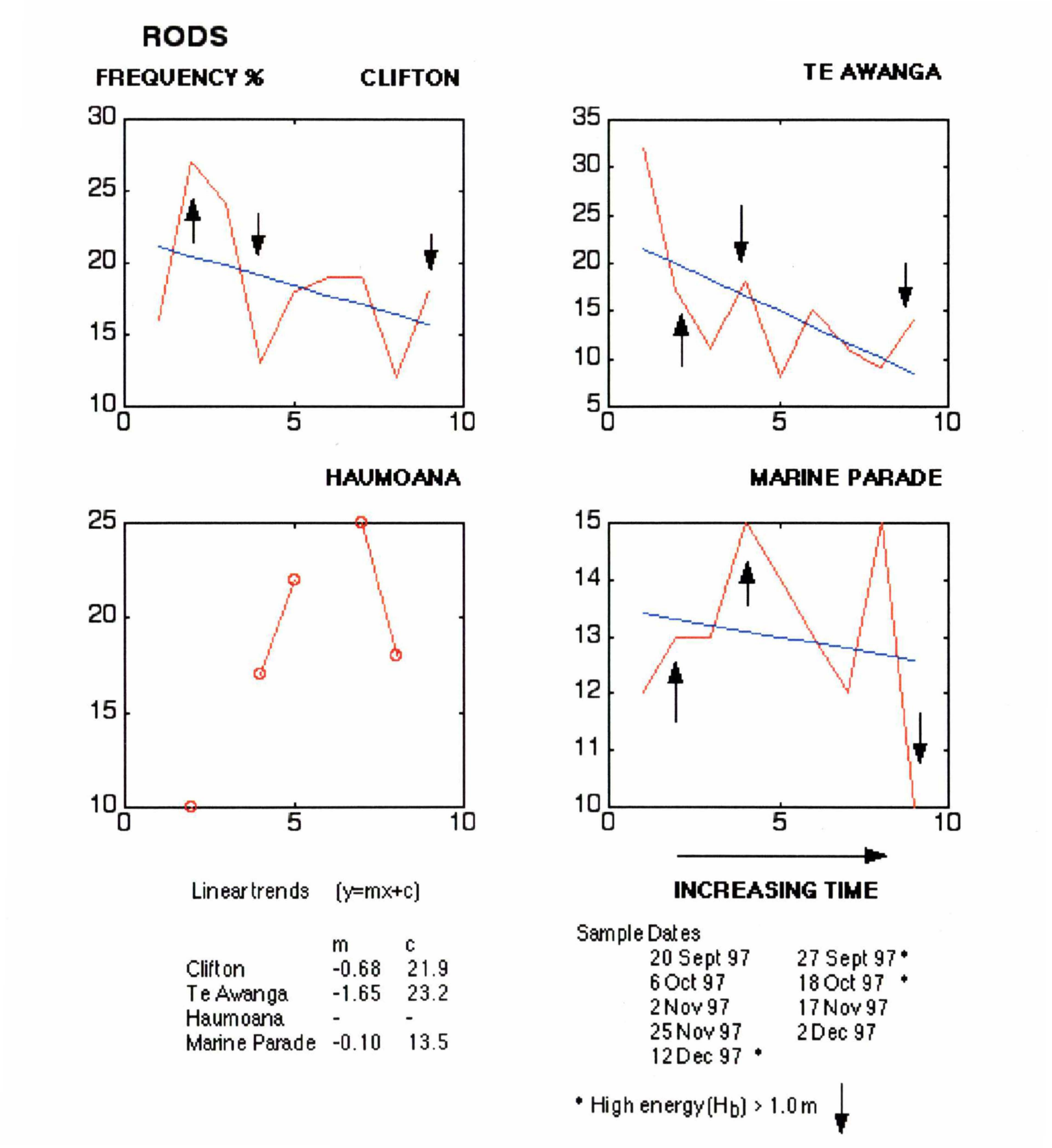
* High energy (H_b) > 1.0 m ↓

Figure 13.2. The disc clast forms over sampling period 20 September 1997 to 12 December 1997. Discs decreased at Haumoana and Marine Parade, at other sites the discs increase.

and decrease at Haumoana and Marine Parade. The discs decreased at Haumoana by some 20%, and Marine Parade decreased by 3%. Increases are generally small with Te Awanga 14%; and Clifton 5%, Disc form variation has the lowest magnitude at Haumoana (11%); and become greater at Clifton (14%); Marine Parade (17%), and Te Awanga with the highest at 23%. Intersample trends can fluctuate or be continuous. A fluctuating sequence example is Clifton between 17 November to 12 December, and a continuous sequence at Marine Parade from 2 November to 2 December.

Rods. (Figure 13.3): -

Over the sampling period, the rodic forms increase at Haumoana (12%), and decrease at all other sites Te Awanga (12%), Clifton (6%), and Marine Parade (1%). Rod variation has the lowest magnitude at Marine Parade (5%); and increases at Haumoana (7%); Clifton (12%); and Te Awanga (13%).



Linear trends (y=mx+c)

	m	c
Clifton	-0.68	21.9
Te Awanga	-1.65	23.2
Haumoana	-	-
Marine Parade	-0.10	13.5

Sample Dates
20 Sept 97 27 Sept 97 *
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 *

* High energy (H_b) > 1.0 m ↓

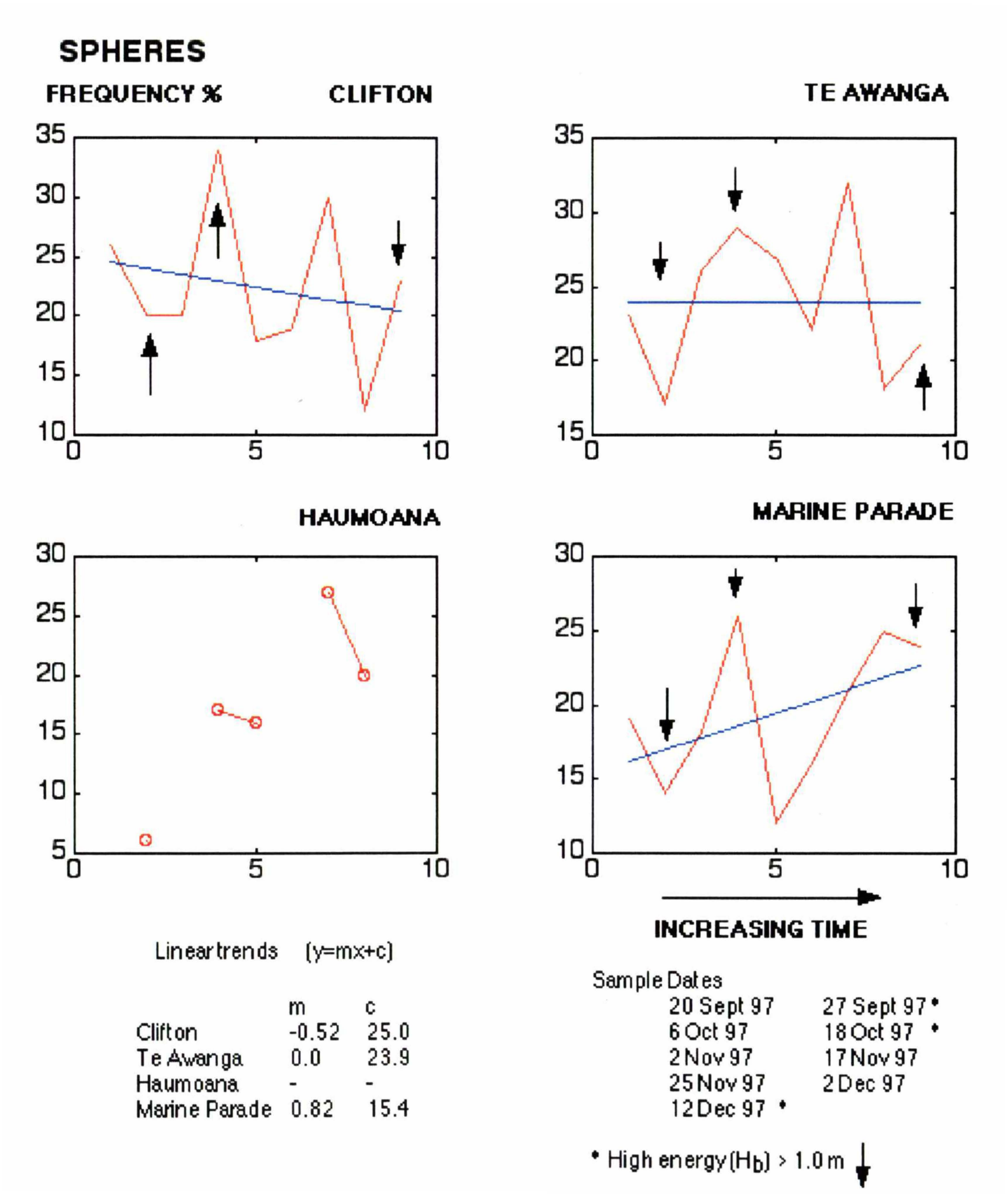
Figure 13.3. The rod clast form evolution from 20 September 1997 to 12 December 1997. Rods decrease at all sites except for Haumoana.

Intersample fluctuations can have some magnitude, for example Clifton between 2 to 12 December 1997. Continuous sequences are present; an example is Marine Parade from 18 October to 25 November.

Spheres. (Figure 13.4): -

Over the sampling period, the spheral forms increase at Haumoana (18%) and Marine Parade (7%). Forms decrease at Clifton (4%). Te Awanga has a 0.0 % trend. Variations of these forms range from a maximum at Clifton and Te Awanga (18%), and decrease to Marine Parade (14%) and Haumoana (8%).

Intersample fluctuations can be regular as at Clifton from 6 October to 2 November Continuous sequence-examples are Marine Parade from 2 November to 2 December 1997.



Linear trends (y=mx+c)

	m	c
Clifton	-0.52	25.0
Te Awanga	0.0	23.9
Haumoana	-	-
Marine Parade	0.82	15.4

Sample Dates

20 Sept 97	27 Sept 97 *
6 Oct 97	18 Oct 97 *
2 Nov 97	17 Nov 97
25 Nov 97	2 Dec 97
12 Dec 97 *	

* High energy (H_b) > 1.0 m ↓

Figure 13.4. The spherical clast form evolution from 20 September 1997 to 12 December 1997.Spheres increased at Haumoana, Marine Parade and Westshore, and decreased at Clifton.Te Awanga had a flat trend.

To summarise the main points of the clast form trends as either increasing or decreasing over a seasonal time period (September to December 1997): -

	Increasing		Decreasing			No trend
Clifton	B	D	R	S		
Te Awanga	D		B	R		S
Haumoana	R	S	B	D		
Marine Parade	S		B	D	R	

Where B blades D discs R rods S spheres

A number of sampling period trends have similarities. For example, the supply sites (Clifton and Te Awanga) have increasing discoidal forms whilst the sink site (Marine Parade) have increasing spherical forms, as does Haumoana (a barrier migration site). Over the same sampling period the blades characterise the decreasing clast forms. The supply sites have characteristic decreasing rods, and at the sink sites rods and blades. However if the entire sample season is viewed, Appendix 7, some forms continue to either decrease, or increase and a few show an apparent seasonal cycle. For example at Clifton the blades continue to increase, but the spheres decrease into summer and increase into winter.

Clast form trends, either +ve (seasonal increase) or -ve (seasonal decrease) can range from steep to low gradient (rate of change) at each site (with no trend at TA): -

	Steep			Low	
Blades	- Hau	+ Clif	-TA	-MP	
Discs	-Hau	+Ta	Clif	-MP	
Rods	+ Hau	-TA	-Clif	-MP	
Spheres	+ Hau	+MP	- Clif		TA 0

Where, Hau (Haumoana); Clif (Clifton); TA (Te Awanga); MP (Marine Parade

In rank order, most form changes occurred at Haumoana, then at the supply sites (Te Awanga and Clifton) and then at the sink site (Marine Parade).

13.3 Longshore Temporal Clast Form Changes.

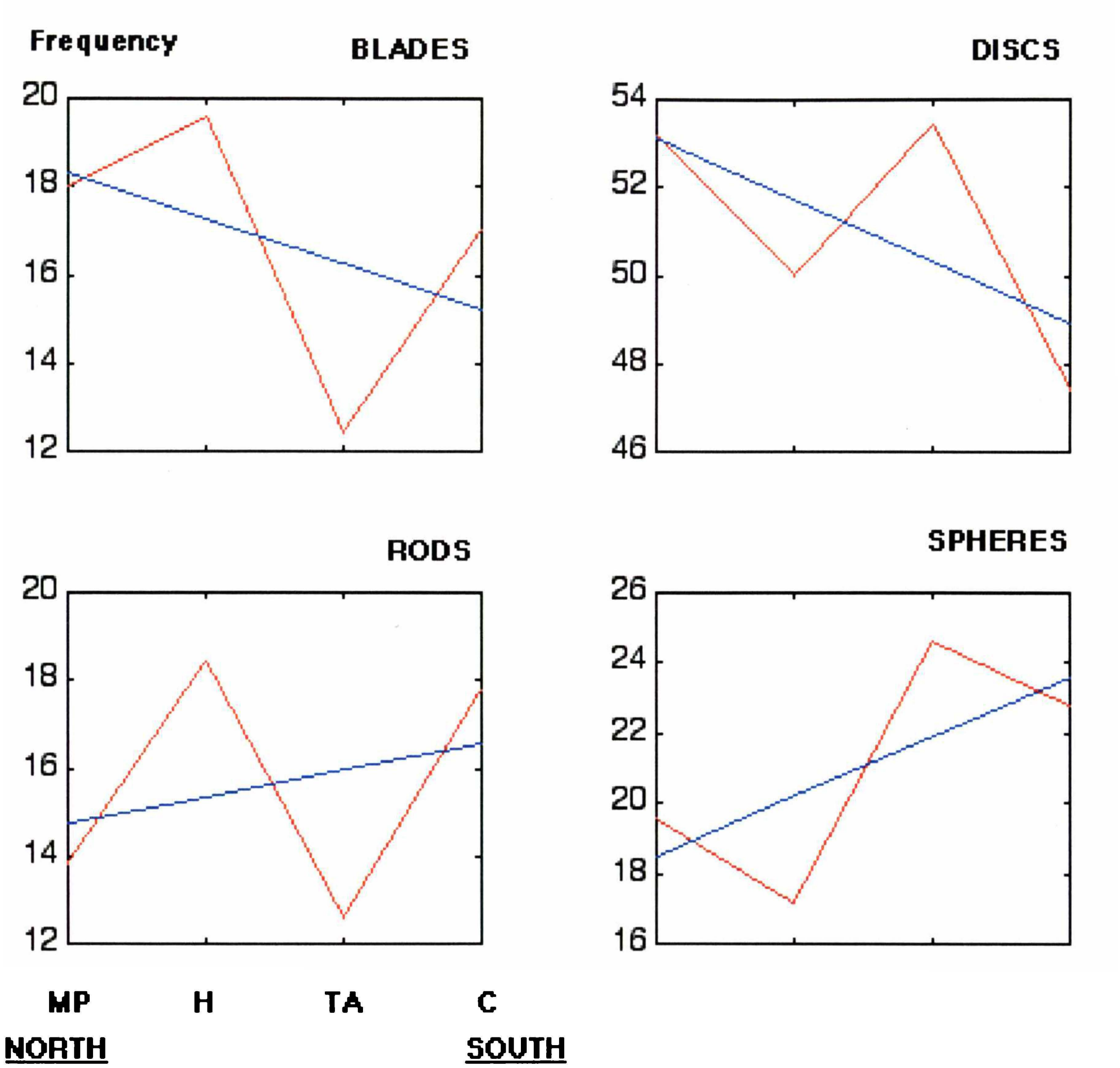
Two further investigations of the springs equinox clast forms are: -

1). Indicate a temporal frame of clast forms alongshore, by summing and averaging 5 samples of clast forms from at each site.

2). Demonstrate and compare the clast form association with clast sizes at the supply (Clifton) and sink (Marine Parade).

13.4 Results.

Temporal frame of clast form changes alongshore.



Linear trends y=mx+c

Parameter	m	c
Blades	-1.02	19.30
Discs	-1.40	54.50
Rods	0.62	14.10
Spheres	1.70	16.80

MP	**Marine Parade**
H	**Haumoana**
TA	**Te Awanga Hall**
C	**Clifton**

Figure 13.5. The average longshore clast forms (ZINGG) blades, discs, rods and spheres. Average for five samples (27 September 1997; 18 October; 2 November; 25 November and 2 December 1997) for each of four southern Hawke Bay barrier low water sites.

Figure 13.5 shows the alongshore clast forms relationships for each site and a polynomial linear fit to obtain an average longshore trend for each clast form. The results show: -

i). Clast form pairs are distinctive. For example, blades and discs increase towards the north (sink), whilst the rods and spheres decrease in the same ‘direction’.

ii). Therefore there is an inverse relationship between (blades and discs) and the (rods and spheres) in the alongshore direction.

iii). In the alongshore direction the local variation can be, and often is, greater than the alongshore trend. For example, the bladed forms at both Clifton and Marine Parade are approximately 18, but Haumoana is

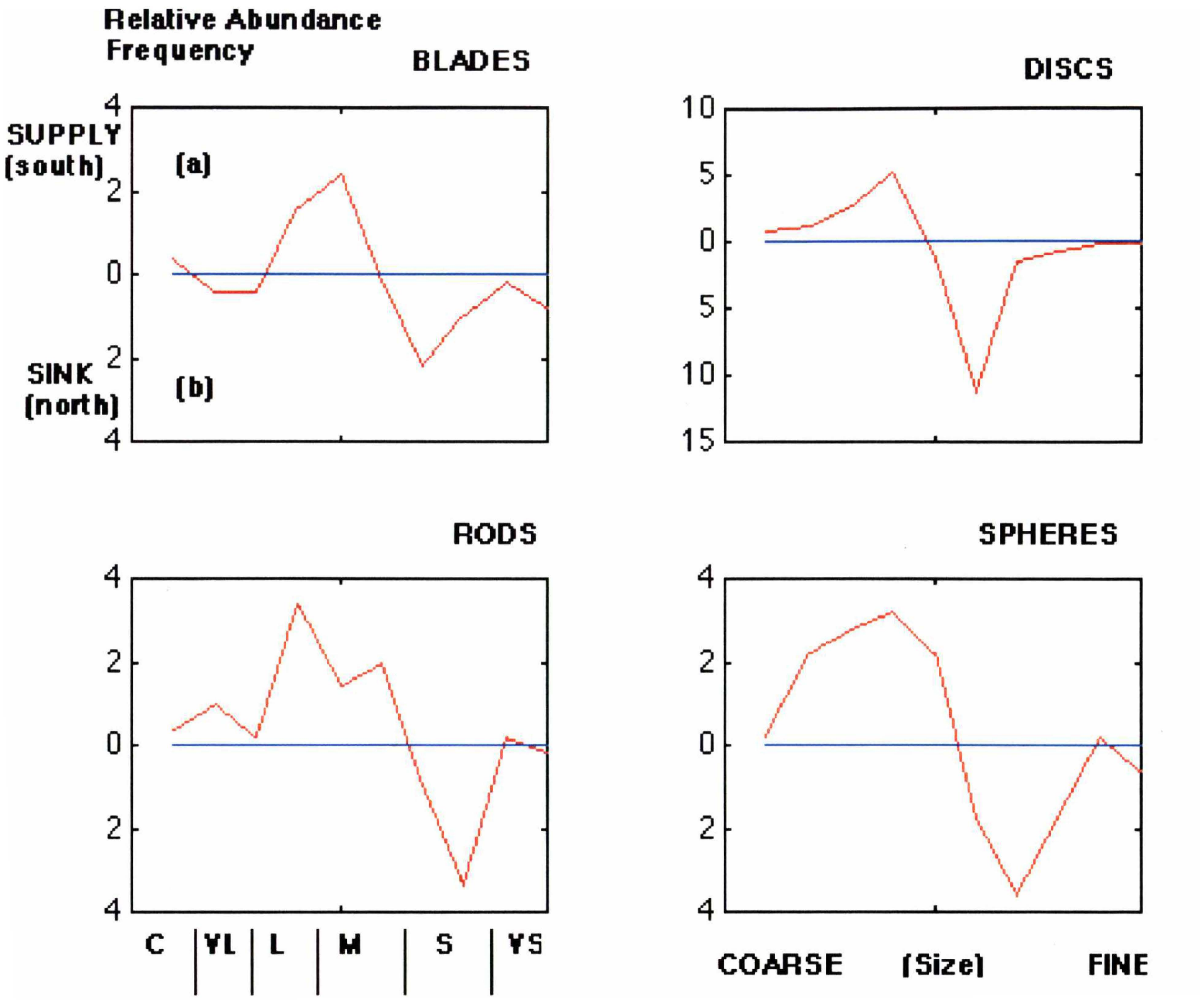
19 and Te Awanga is 13. Also in the alongshore direction the values alternate, there is no smooth gradual increase or decrease of clast form in the alongshore direction. Whilst there is an overall form pair grouping, for example blades and discs increase alongshore together the pair grouping breaks down between sites. For example, the blades and discs do not increase together between Clifton and Te Awanga, discs increase but blades decrease. In this local example, the discs increase with the spheres. The linear fit gradient measuring the rate of change alongshore is of interest. The greatest rate of change is associated with the spheres (1.70) and discs (-1.40) and the least is the rods (0.62) and blades (-1.02). Note that the rate of change or least squares gradient is either positive, or negative by convention from the left (Marine Parade) towards the right (Clifton), but in Hawke Bay the alongshore drift is from Clifton to Marine Parade.

Clast form (ZINGG) and size (Phi) associations at the supply (Clifton) and sink (Marine Parade).

Whilst Figure 13.5 demonstrates the clast form changes in the longshore direction at the low tide beachface there is no indication of the clast form changes in relation to the sizes of the clasts and their relative abundances. Figure 13.6 indicates the relative abundance of the clast forms in each Phi size class in the alongshore direction. Two sites demonstrate these relative abundances, Clifton (supply) and Marine Parade (sink), and represent clast form-size changes over an n alongshore distance of some 16 km.

The form-size data at each site comprise the clast forms (columns) and sizes (rows) arranged as a matrix. Each site has five sample dates (see Figure 13.5 for sample dates) available to produce an average summer equinox matrix. Subtraction of these average equinox matrices produces the relative abundance frequency, or a residual frequency matrix. Since the relative abundance frequency is a residual of two frequency data sets, the upper half on Figure 12.6 represents Clifton. At Clifton, the discs have a small cobble (-6.0 Phi; larger than 64 mm) population whereas Marine Parade does not have any cobble sized discs. At Clifton, the spherical form population increases to a maximum in the small large size class (-4.0 to -4.5 Phi; 24 to 16 mm). In the finer disc sizes, Clifton has fewer small and very small discs in comparison (relative) to Marine Parade. Marine Parade has an abundance of discs in the small medium size class (-3.0 to -3.5 Phi; 12 to 8 mm).

From this we can construe the discs are most frequently large at Clifton whilst at Marine Parade the discs dominate the smaller sizes. The process leading to the shift of form-sizes alongshore could be a function of abrasion as the clasts transport some 16 km, or size selection in an increasing alongshore energy gradient. Figure 13.6 also indicates that the discs have nearly equal proportions in the very small, to small size classes at both Clifton and Marine Parade. Perhaps, if the clasts abraded the small clast population should increase in both time and as distance increased.



Clast sizes			Phi
C	cobble		-6.0 and larger
VL	very large		-5.0 to -6.0
L	large	large	-5.0 to -4.5
		small	-4.5 to -4.0
M	medium	large	-4.0 to -3.5
		small	-3.5 to -3.0
S	small	large	-3.0 to -2.5
		small	-2.5 to -2.0
VS	very small	large	-2.0 to -1.5
		small	-1.5 to -1.0

Figure 13.6. Clast form (ZINGG) and size (Phi) relative abundances at a supply (Clifton (a)) and a sink (Marine Parade (b)), Hawke Bay. (Data dates are the same as those for Figure 13.5).

Figure 13.6 indicates: -

1). Clifton (supply).

(a). All forms, except very large blades, are coarser relative to Marine Parade.

(b). Larger (cobble to large medium) sizes in rank order are discs, rods, spheres and blades.

(c) Frequency peaks are similar for discs, rods and spheres in the small large (-4.5 to -4.0 Phi; 24 to 16 mm) size class.

(d). Blades have a frequency peak size in large medium (-4.0 to -3.5 Phi; 16 to 12 mm).

(e). In the large and very small sizes, both rods and spheres have a frequency greater than Marine Parade.

(f) Rods are present over a greater size range than other forms.

2) Marine Parade (sink).

(a). Clast forms are generally finer than Clifton.

(b). The few very large sizes are blade dominated.

(c). Finer (very small) sizes in rank order are blades, spheres, rods and discs.

(d). Frequency peaks range from small medium discs (-3.5 to -3.0 Phi; 12 to 8 mm), large small blades and spheres (-3.0 to -2.5 Phi; 8 to 6 mm), and small small rods (-2.5 to -2.0 Phi; 6 to 4 mm).

(e). There appears to be greater size form restriction at Marine Parade, size form distributions have less size range compared to Clifton.

(f). Discs are present over a greater size range than the other forms.

(g). There is a two-fold increase in the peak frequency of discs compared to Clifton. The peak frequency at Marine Parade is in the small medium size class, where-as the peak disc frequency at Clifton is in the small large size class.

13.5 Oblate Prolate Index and Maximum Projection Sphericity of Hawke Bay Clasts.

Results.

Figures 13.7 and 13.8 are the oblate prolate index (OPI) and the maximum projection sphericity (MPS) temporal (seasonal) trends. From these data it is possible to obtain the temporal evolution of clast forms, and explore the alongshore energy gradient relationships.

The long trend of the OPI forms can be an increasing -ve value (increasing discoidal), for example Te Awanga, and Marine Parade or can show the reverse where forms become more +ve (increasing rod form where Haumoana does have indications), or can remain almost stationary (the bladed form at Clifton). An extended long trend (Appendix 7) could suggest seasonal influences.

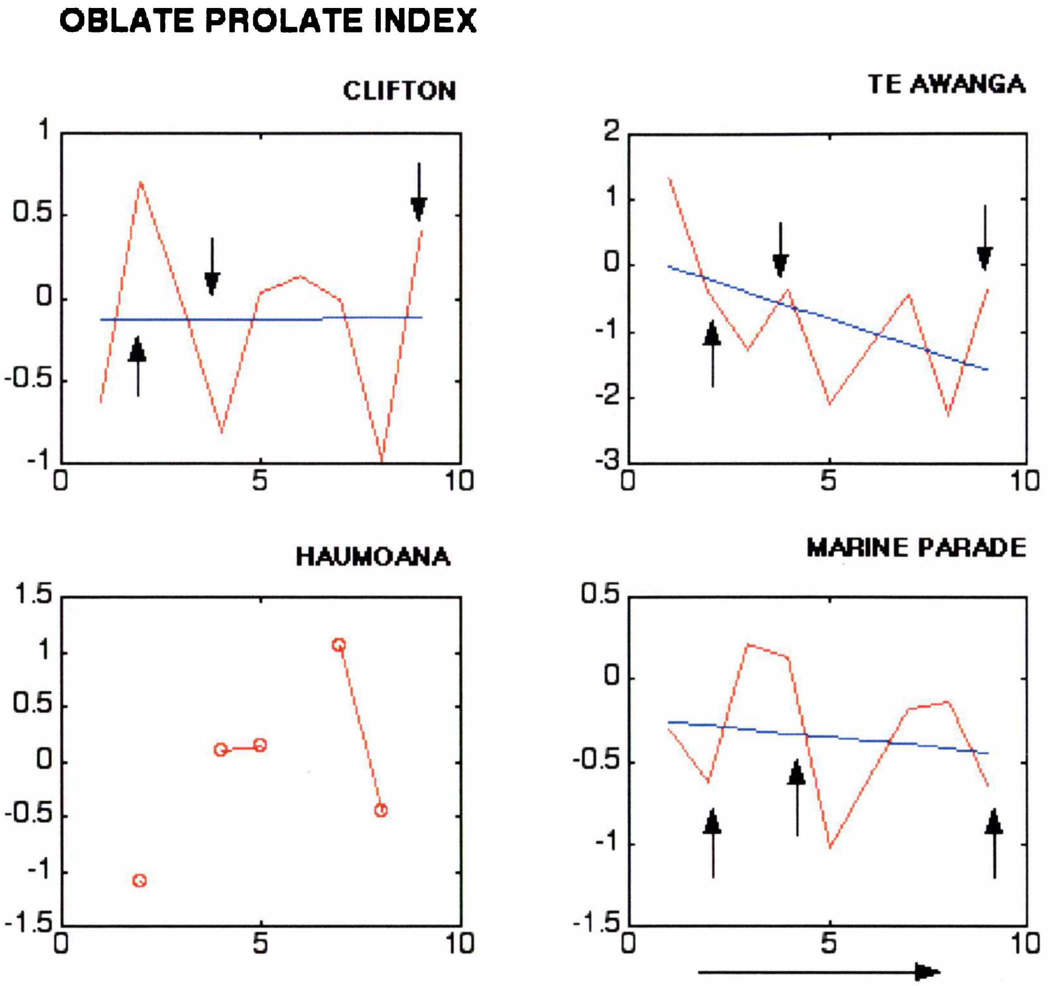
In general, terms the form parameters OPI and MPS characteristics are: -

1). The magnitude of OPI variation is least at Marine Parade (range of form, bladed becoming more oblate or discoidal) and Te Awanga has the greatest (where forms can range from bladed +ve rod like to -ve discoidal). Intersample trends can fluctuate or be continuous. Clifton has a fluctuating sequence from 20 September to18 October. A continuous sequence is well defined at Marine Parade from 2 November to 2 December.

2). Over the sampling period the MPS forms can increase (increasingly compact-isometric) or decrease (increasingly discoidal). Increasing compactness occurs at Haumoana, and Marine Parade, whilst increasing discoidal forms are at Clifton and Te Awanga. The magnitude of MPS change is least at Te Awanga (forms becoming discoidal) and Haumoana has the greatest (from discoidal to compact).

Intersample MPS form changes can fluctuate or be continuous. For example, Te Awanga has a sequence of fluctuation from 25 November to 12 December and Clifton a late sequence from 17 November to 12 December.

The relationship between the longshore energy gradient and the OPI and MPS clast forms is by averaging the parameters at each site, (Table 13.1).



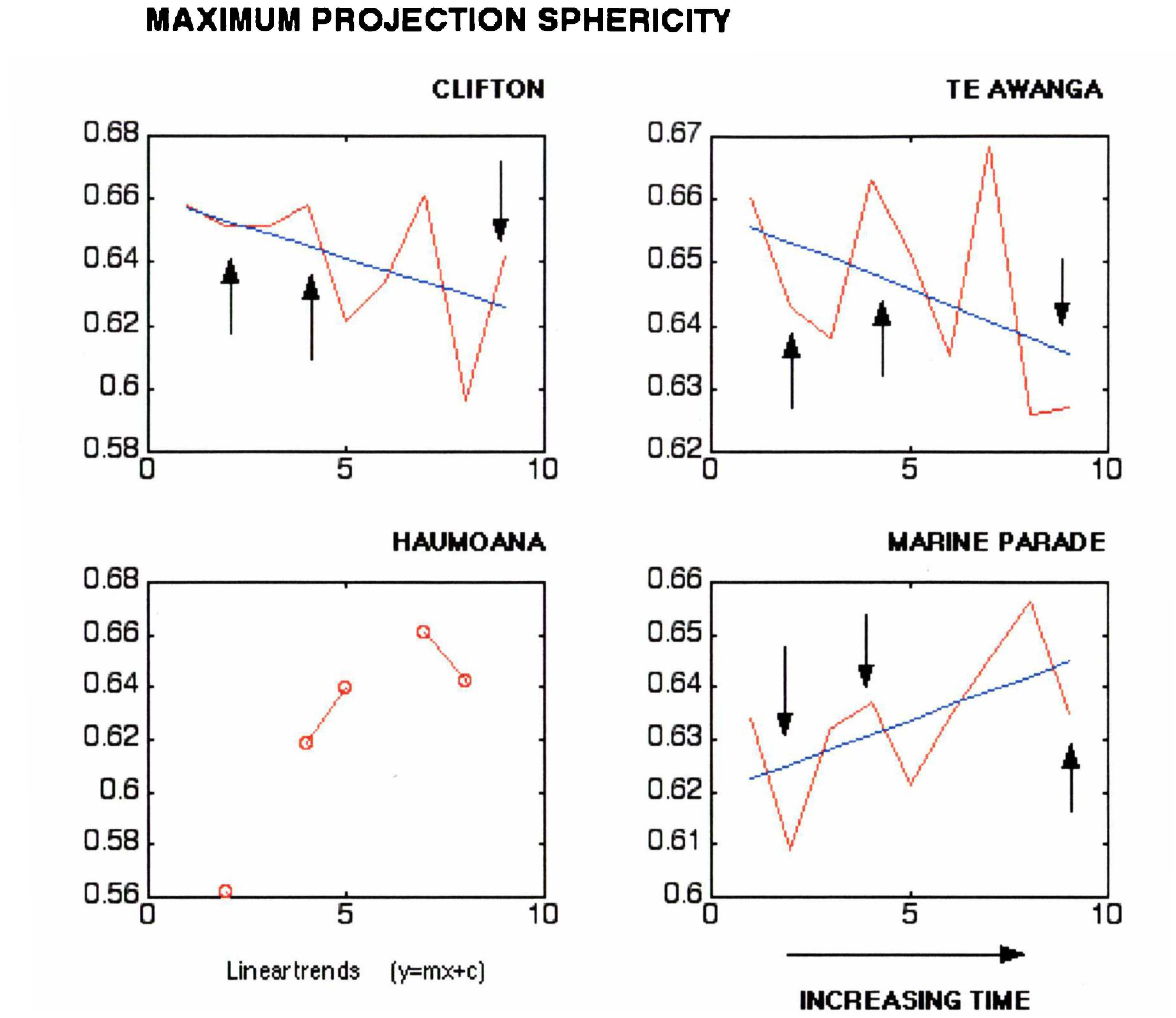
Linear trends (y=mx+c)

	m	c
Clifton	0.002	-0.14
Te Awanga	-0.19	0.18
Haumoana	-	-
Marine Parade	-0.02	-0.24

Sample Dates
20 Sept 97 27 Sept 97 •
6 Oct 97 18 Oct 97 •
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 •

• High energy(H_b) > 1.0 m ↓

Figure 13.7. Oblate-prolate index forms over sampling period from 20 September 1997 to12 December 1997. Clasts became more oblate (discoidal) at Te Awanga. At Haumoana, the clasts have distinctive increasing prolate (rod) forms.



Linear trends (y=mx+c)

	m	c
Clifton	-0.004	0.661
Te Awanga	-0.003	0.658
Haumoana	-	-
Marine Parade	0.003	0.619

Sample Dates

20 Sept 97	27 Sept 97 *
6 Oct 97	18 Oct 97 *
2 Nov 97	17 Nov 97
25 Nov 97	2 Dec 97
12 Dec 97 *	

* High energy (H_b) > 1.0 m ↓

Figure 13.8. Maximum projection sphericity forms over sampling period from 20 September 1997 to 12 December 1997. Clast forms became increasingly compact at Haumoana, and Marine Parade, and more discoidal at Clifton and Te Awanga.

ENERGY GRADIENT

LOW ——→ **HIGH**

Mean	**CLIFTON**	**TE AWANGA**	**MARINE PARADE**
OPI	-0.131	-0.806	-0.354
MPS	0.641	0.646	0.634

Table 13.1. The relationships of clast form OPI and MPS to the alongshore energy gradient (average for n=9 samples at each site, same dates as for sampling period trends).

13.6 Discussion of Clast Forms and Sizes.

Temporal scale variations of the clast forms vary. For example at a particular site the intersample variation of a clast form can be greater than the spring-summer long trend. The discs at Clifton are an example (Figure 13.2). Over the long trend season, the discs increased from winter to summer by some 5%, but the intersample variation from 17 November to 12 December was some 17%. By comparing the long trend clast forms (September to December 1997; Figures 13.1 to 13.4) to the complete data set from spring to autumn (September 1997 to April 1998-Appendix 7) some clast forms continue to 'change' (either decrease or increase), whilst others change seasonally. For example at Clifton, the bladed and discs forms continue to increase from September 1997 to April 1998, and rods continue to decrease. On the other hand, the spheres have a seasonal 'cycle' and first decrease (from September 1997 to December 1997) and then increase into April 1998.

ORFORD (1975) found using multivariate clustering that the clast shapes (forms) have a seasonal relationship typified by low and high energy (air mass and incident wave energy). This seasonality may explain the variation of spheres with an increase associated with winter high seas, but it does not explain the 'steady' increase or decrease the other forms, for example blades. At Clifton, the blades continue to increase over the September to April 1997-98 season and continue to decrease at Te Awanga, Haumoana and Marine Parade. This suggests the supply dominates the sorting processes at Clifton, since to the north the blades decrease over the same time period.

The HB spherical form could therefore be expected to increase in high seas at the low water cusp sample sites. Inspection of Figures 13.2 and 13.4 shows in some instances spheres do increase and discs decrease on a high seas event, viz. Clifton 12 December. However, on the two other high seas events, firstly, 27 September both spheres and discs decrease, and secondly 18 October the spheres do increase, but the discs remain constant. The other sample sites also show some consistency of form pair relationships to process.

On an evolution scale, the paired clast forms could explain the observed distribution at Haumoana in response to rollover process. Haumoana is a known 'erosion' barrier length and the large-scale reduction of the discs and blades with increasing rods and spheres could indicate a rapidly transgressive barrier. Conversely, Marine Parade also has decreasing blades, discs and rods and is a known accretional, sink length of barrier.

BLUCK (1967, Figure 4) reports the clast form changes over a longshore distance of some 200 m for the low energy MSG Newton Beach. Samples from the outer frame have the greatest frequency of spherical and rod forms and these forms are continuously moving. BLUCK (1967) demonstrates two clast form pairs, firstly discs and blades, and secondly rods and spheres. Depending upon the prevailing hydrodynamics, it is possible that some pairs of forms may have common responses when currents flowing across the beachface sort clasts by a process of hydrodynamic selection of 'equivalent' sizes. For example a disc and a sphere may have the same size, however, since the disc form has less mass it lifts further up the beachface than the spherical clast that tends to transport by rolling in the backwash drag (LANDON, 1930; ORFORD, 1975). An extension of this idea would suggest that the blades and discs would form a lag deposit beachface and the more mobile rods and spheres would transport alongshore to deposit further a field. Figure 13.5 shows the clast form pairs, recognisable by their similar linear fit gradients. The pair blades and discs increase from Clifton to Marine Parade and the pair rods and spheres decrease. Therefore, the HB alongshore beachface is contrary to what is expected on clast form sorting. Clast form abrasion in the alongshore direction could explain the dominance of bladed forms at Marine Parade where these clasts could, as KUENEN (1964) suggests, be a result of prolonged abrasion as the clast edges abrade hence the pebbles become increasingly prolate (shift towards bladed forms).

BLUCK (1967) found in the longshore direction from north to south the Newton Beach, South Wales, clast form changes were (i) blades change from coarse, becoming finer, (ii) discs, few coarse fairly uniform, (iii) rods increasing to finer sizes, and (iv) spheres mostly coarse decreasing towards finer sizes. At the high energy Sker Beach, South Wales, the proportions of spheres and rods increase in the finer sizes alongshore over a distance of some 200 m BLUCK (1967). WILLIAMS and CALDWELL (1988) mention the shore parallel proportions of spheres and discs seem to be important for South Wales beaches. Figure 13.6 demonstrates the alongshore changes of the sizes and forms between the supply low energy beach at Clifton and the high energy, sink site at Marine Parade. All clast forms are mostly represented by the coarse sizes at Clifton and the finer sizes at Marine Parade. Within this generalization the Marine Parade site has an 'outlier' of coarse blades, and these could be rapid transport over pass clasts.

Irrespective of the longshore spatial differences between HB and South Wales, it appears there are similarities in the longshore change of clast forms as described by BLUCK (1967) for South Wales. At both field sites in the longshore direction the blades, rods and spheres become finer, however, the HB low water discs are not uniform alongshore and the data suggests an increase (two fold) of finer discs.

DOBKINS and FOLK (1970) suggest the OPI and MPS are good environmental discriminating parameters, where the gravel forms from the environments of river, low and high energy beaches are: -

Environment	OPI	MPS
River	+0.18	0.684
Low wave energy	-0.81	0.640
High wave energy	-2.13	0.584

In more detail DOBKINS and FOLK (1970) found: -

1). High energy beaches show greater range of OPI, where all the OPI parameters are -ve (discoidal) as a mean value within size classes and as these become larger. Low energy beaches have an increasingly more +ve POI (increasingly more rod form) as size classes become larger. DOBKINS and FOLK (1970) observed marked alongshore change of OPI, and considered this to indicate abrasion, or selective sorting on a sandy substrate, where discs are trapped by sands.

2). High-energy beach MPS have a wide range of values, a function of wave energy and sand content. Generally, the MPS decreases as size classes become larger. Low energy beaches generally have the lowest MPS associated with the smaller size classes, especially when the beach is sandy. The largest size classes move only in storms and these sizes have the lowest MPS.

DOBKINS and FOLK (1970) note MPS has a small range of values at sites and has greater spatial variation. The local site variation of MPS and size can be distinctive, indeed local spatial distributions of gravels correlate to the cuspate morphodynamics on an indented beach in Northern Ireland (SHERMAN, et al., 1993).

On the other hand BARTHOLOMA, et al. (1998) suggest an opposite series of trends along the 8 km (Calabria) Bianco Beach, firstly the OPI has no change of "meaningful interpretation" and secondly alongshore variation of MPS has "no noteworthy change", where MPS decreases 0.05 (granite) to 0.06 (gneiss) units. The greatest OPI discrimination was in the cross-shore direction. Towards the north and alongshore the clast MPS decreases (becoming more discoidal) and the standard deviation (SD) slightly decreases, but also appears to increase in the range of SD (Figure 3, p. 143, BARTHOLOMA, et al. (1998)). Grouping all OPI parameters there is a slight increase towards more +ve OPI (rod increase) towards the north.

For the HB the postulate is the greater the longshore spatial sampling coupled with an increasing energy gradient the greater the alongshore gravel form variation. In addition, there could be similar form variations associated with wave energy event (wave height m), as suggested by CARR (1971). When translated into a summer-winter seasonal scale, the variations should be more definite.

Results from the HB, Figures 13.7 and 13.8 show a slight alongshore change with the OPI having a negative (discoidal increasing) increase and the MPS decreases (becoming more discoidal) towards Marine Parade. However, intersample variation at a site can be greater than the overall seasonal change in the alongshore direction. Note too at sampling intervals the clasts have similar parameter response to the prevailing hydrodynamics. In response to a high energy event some sample sites have a similar trend, for example (Figure 13.7) OPI all three high energy wave events (H_b > 1.0 m) the OPI changes in the same direction: -

1). Clifton from -ve (discs) to +ve (rods).
2). Marine Parade has an opposite form change, forms change from more +ve (rods) to more -ve (disc).

HB forms associated with increasing alongshore energy gradient should see an increasingly negative OPI from supply (Clifton-Te Awanga) to sink (Marine Parade), and similarly MPS should decrease in the same direction. In HB the alongshore changes towards a higher energy environment (between Clifton and Marine Parade) are: -

1). OPI does become more -ve, and
2). MPS does decrease.
3). The greatest variations of MPS and OPI expected at Clifton near the Cape Kidnappers (fluvial environment of deposition) conglomerate supply do not exist.

These gravel form associations show the supply and sink can have a form change, where the low energy supply has a change to rods and the high-energy sink to discs. This suggests form changes in response to hydrodynamics can occur in an energy gradient in the alongshore direction.

13.7 Cross-shore Form Changes with Wave Energy Events.

Using the same events stipulated in Chapters 10 and 11: -

1). Moderate wave energy, (26 September, 2000) and
2) High wave energy (3rd to 6th June 2000).

This section examines the change of the gravel forms associated with these two increasing wave energy events. Clast form OPI and MPS parameters can have environmental distinctive values based upon their respective mean and standard deviation (DOBKINS and FOLK, 1970; BARTHOLOMA, et al., 1998).

Results. Moderate Wave Energy. Erosion Te Awanga Hall.

To recap the late September 2000, morphodynamics (Chapter 10; Section 10.2): -

1). Waxing wave steepness,

2). Decreasing beachface slope, a HW sap erosion

3). Increasing Iribarren number,

4). Profiles indicate two morphodynamic conditions: -

a). Supply: HW erosion-LW accretion,

b). Sink: HW overtop deposition, LW erosion (?) (Marine Parade).

5). Gravels represent lag gravels at HW and LW sites, except LW Clifton (low energy transport state) according to the McLAREN (McLAREN and BOWLES, 1985) model for the textural statistical parameters.

The OPI and MPS parameters at each site (Table 13.2) are defined by their mean and standard deviation (SD). The standard deviation could indicate a measure of sorting of clast form For example, the OPI standard deviation could correspond to the clast grain size standard deviation that is a measure of sorting. Therefore, if both decrease the indications are that sorting improves (become well sorted) in the same cross-shore direction (up the beachface).

As it is this does not appear to be viable, for example Figure 13.10 (late September 2000) Clifton and Te Awanga Hall sorting parameters, and Table 12.2 OPI and MPS clast form parameters.

For the moderate energy event (late September, 2000) at most sites the LW OPI are +ve and, the HW sites are -ve.

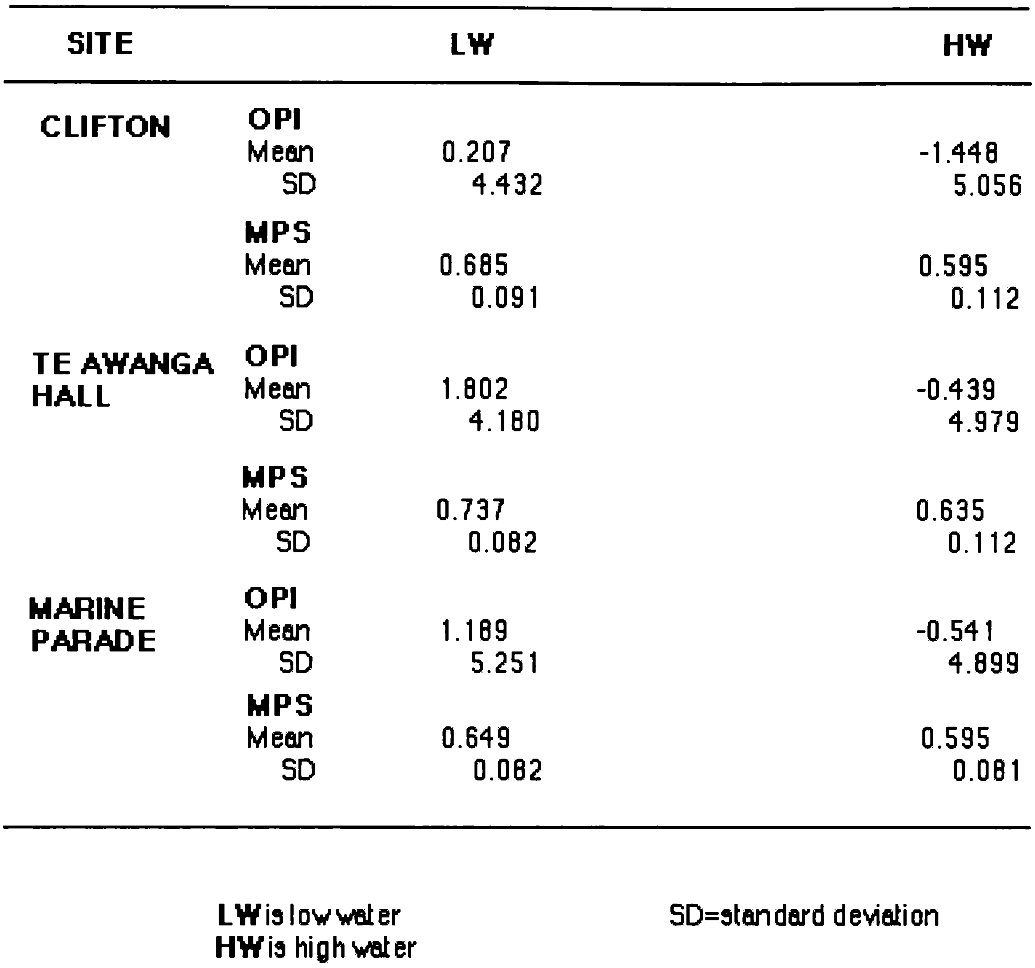
HB HW samples are all -ve and therefore more oblate (disc form) and the LW samples more +ve, and are more prolate (rodic).

The MPS values (Table 13.2) are less at the HW sites relative to the LW. These HW gravels are therefore more flat (discoidal) than the corresponding LW sites where clast forms are more compact (spherical).

In the alongshore direction (Table 13.2) the relative form parameters were: -

Supply	The average OPI is relatively more oblate and the MPS more compact.
Sink	Clast OPI is more prolate, and MPS increasingly discoidal.

In the alongshore direction there is no apparent well-defined steady gradient of form between a parameter maxima and minima. The OPI SD does have a very small gradient from Clifton (5.056) to Marine Parade (4.899), but not enough to draw a clear meaningful conclusion. This supports the idea that a local variation can be greater than the alongshore gradient of a clast form parameter.



SITE		LW	HW
CLIFTON	OPI		
	Mean	0.207	-1.448
	SD	4.432	5.056
	MPS		
	Mean	0.685	0.595
	SD	0.091	0.112
TE AWANGA HALL	OPI		
	Mean	1.802	-0.439
	SD	4.180	4.979
	MPS		
	Mean	0.737	0.635
	SD	0.082	0.112
MARINE PARADE	OPI		
	Mean	1.189	-0.541
	SD	5.251	4.899
	MPS		
	Mean	0.649	0.595
	SD	0.082	0.081

LW is low water
HW is high water

SD=standard deviation

Table 13.2. High (HW) and low water (LW) gravel form parameters (OPI and MPS) in a moderate high seas event (late September 2000), for the supply (Clifton and Te Awanga) and sink (Marine Parade).

Results, High Wave Energy Deposition, Te Awanga Hall.

This section examines the transgressive gravel forms associated with the formation of a HW ridge. Figure 13.9 summarises the OPI and MPS mean values and standard deviations associated with the sediment accretion at a HW ridge at the Te Awanga Hall site.

The OPI changes are: -

1). Initially, on 3 June, for the overwash deposit, the OPI values in the cross-shore up beachface direction (S3 to S1) near perfect blades, become more discoid and at S1 clasts are more rodic.

2). On 6 June, for an overtop deposit, the OPI reverses where in the up beachface direction the clasts are more elongate (S3), at the HW ridge crest (S2) near perfect blade, and at S1 more oblate (discoid).

3). Standard deviations are greater on 3 June than 6 June. The standard deviation increases up beachface on both sample runs.

The MPS changes are: -

1). The 3 June MPS values have negligible change in the up beachface direction. If anything, the value is greater at S2, suggesting a marginally more spheric clast suite.

2). On 6 June in the up beachface direction the relatively greater value (S3) decreases at the crest (S2), and then increases at S1, so the clasts at S3 are more spherical, at S2 more discoidal and at S1 increasingly spherical.

3). Standard deviations on 3 June are greater than on 6 June. There are no apparent gradients of increasing standard deviation. There is some indication of the greater standard deviation at S1 on both sample run occasions.

13.8 The Combined Form Parameters, the Moderate and the High Wave Energy Events at Te Awanga Hall.

It is possible to combine the moderate and the high wave energy events to determine the similarities of the clast form parameters.

Results.

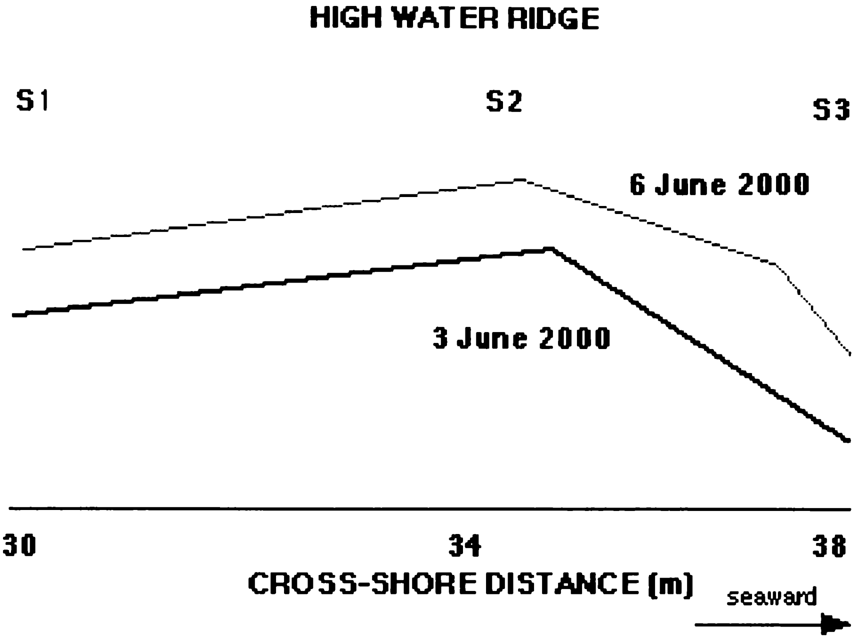
Results for the moderate energy event (late September 2000; Table 13.2) indicate the OPI values become -ve towards the HW (more discoidal). The high wave energy event (June 2000) does have similarity (Figure 13.9). The OPI parameter associated with the overwash deposition (3 June) is most -ve at the HW ridge crest (S2) than deposits too seaward (S3). On 6 June the overtop deposits are also more -ve, or increasingly discoidal. The 'anomaly' here is the highly +ve OPI at S1 on 3 June. This result shows the most landward transported gravels are mostly rodic, and not discoidal. Further, on 6 June sediments that welded onto the depositional HW ridge had +ve OPI rods transported to maximum run-up zenith.

The MPS parameters indicate the moderate energy event clast are more discoidal towards HW. The high-energy event deposits have negligible change towards the overtop deposition site (3 June), and a discoidal form at the overwash deposition site (6 June).

Discussion, the Clast Form in Moderate and High Wave Energies.

Somewhat contrary to the expected gravel form changes BARTHOLOMA, et al. (1998) found the OPI and MPS values, had most differentiation in the cross-shore direction, with discs towards the backshore (landward of beach crest) and increasingly compact (spherical) offshore. On closer inspection of BARTHOLOMA, et al. (1998) the greatest alongshore change of both OPI and MPS takes place along the backshore (from south to north, the direction of longshore drift, and possibly the energy gradient increase with waves produced by southerly winds).

In the alongshore direction the HB LW gravel forms do not have a steady gradient between a maxima and a minima. By grouping the HB OPI and MPS parameters into a supply and a sink, the LW OPI has a small increase towards more +ve OPI forms (increasing rod form), and the MPS a small decrease (forms become more disc form) towards the sink. The corresponding HB HW suites have the greatest OPI change, with forms becoming more +ve (increasing rods) whilst the MPS have negligible change. Both the OPI and MPS have greater 'local' variation for example, Te Awanga parameter values are greater especially at LW) than the 'expected' gradient in the alongshore wave energy gradient.



	SAMPLE SITE		
	S1	S2	S3
6 June 20			
OPI			
Mean	-1.204	0.349	0.779
SD	5.435	5.146	4.760
MPS			
Mean	0.645	0.618	0.672
SD	0.099	0.087	0.098
3 June 20			
OPI			
Mean	1.829	-1.236	-0.047
SD	5.714	5.309	5.035
MPS			
Mean	0.661	0.665	0.662
SD	0.122	0.079	0.108

*Figure 13.9 Te Awanga Hall. Gravel form parameters, oblate-prolate index (OPI) and maximum projection sphericity (MPS) for an accretional event at a HW ridge, from 3 June to 6 June 2000. (**SD** is standard deviation).*

There is also the aspect of antecedent morphology on subsequent deposition. . For example in this instance the HW gravels are from an antecedent HW ridge and comprise lag gravels from previous overtop deposition. The moderate energy event took place on gravels from a HW ridge that has undergone sap avalanche erosion, except for Marine Parade. Marine Parade is an overwash deposit. The sorting of the sap material has produced a classic lag at HW of more -ve OPI (residual discs) and lower value MPS parameters (residual discs. What this sequence does show is the disciness of the HW lag and the more spherical deposit at LW, which fits the general models proposed and demonstrated by LANDON

(1930). However, Marine Parade is odd, since it was an overtop deposit. This suggests deposition of material that is 'available' (previous HW ridge) and redeposition further up the beachface.

Using the OPI parameter, in the direction of energy increase the high-energy beachface clasts would become more platy, very platy and very bladed (DOBKINS and FOLK, 1970) where these forms are generally discoidal, or increasingly -ve (Chapter 8, Figure 8.4). The HB beachface gravels do not have these more platy forms being more restricted to bladed forms. However the more energetic HB deposits (overtop and overwash) usually have increased -ve OPI compared to gravels too seaward and are therefore generally more discoidal. The anomaly of relatively high +ve OPI associated with the 3 June 2000 overwash at S1, the most landward sample, suggests that rods transport the greater distance landward. But, on this occasion the HW ridge crest (S2) was also highly -ve (discoidal). This suggests that the discs, by laying flat effectively armour the surface and rods can not lodge, so roll further landward as overpass. High-energy beaches have low values of MPS with the decreasing values associated with increasing energy (DOBKINS and FOLK, 1970). DOBKINS and FOLK (1970) suggest not only the mean values of the form parameters can distinguish between coastal fluvial and beach environments, but further differentiation is also seen with the form parameter standard deviations (SD).

Hence OPI SD: DOBKINS and FOLK (1970, Table 7, p.1189) show the standard deviation (SD) is greater for high energy beaches, less for low energy beaches and least for rivers. Indeed this seems to be the case for some sample arrangements, for example the LW samples (Table 13.2, compare the OPI SD), Clifton LW OPI SD = 4.43 to Marine Parade OPI SD = 5.25, however HW OPI SD has a reverse trend.

DOBKINS and FOLK (1970) thought MPS changes are a product of abrasion, by extension this suggests the longer a pebble is in, or traveling towards, a high energy beach the greater the abrasion and subsequent reduction of MPS values and the OPI becomes increasingly more –ve.

Beach pebbles generally have low value MPS SD and a sand content could further reduce the values of MPS via the process of abrasional sliding across the sandy surface, where this is most applicable to the smaller sized clasts. Marine Parade clasts should therefore have the least mean MPS and least MPS SD, since these clasts are smaller, and have slide further and over a greater length of time when compared to the supply clasts at Clifton. These Clifton gravels are mostly Late Pleistocene fluvial deposits that should have a greater average MPS than their contemporaries on the nearby beachface. At Clifton the swash sorting processes of cliff fall (ex-fluvial) material could be very rapid since the beachface MPS HW values are not typically fluvial but show distinctive high energy beach characteristics with low value MPS. At Clifton, the HW clasts (September 2000) have a low value mean MPS where this may be a function of high energy deposition in the cross-shore direction. Indeed this is applicable to Marine Parade where the HW mean MPS is less than the LW average MPS. At Te Awanga Hall in the cross-shore direction at the HW the gravel MPS can have a low value and greater SD when compared to the adjacent LW (September 2000), but with overwash and overtop deposition (June 2000) the MPS change is slight, with a marginal reduction of MPS SD as energy of event increases (from 3 June to 6 June). The MPS parameter results suggest in certain circumstances as the sea energy increases material from the upper beachface projects by saltation up the beachface and it this material that overwashes with little 'sorting'.

That forms do not have a seasonal fluctuation suggests that either they are stable in a particular locality, or that the supply of particular forms swamps the sorting process, or that the data period only covers part a longer cycle. Forms do not appear to be stable at a particular locality, but continue to change. However, local intersample variations are in the same order as the seasonal change and local variations of wave sorting could account for the 'seasonal' expression. For example, the spheres at the LW sample sites should increase in high-energy seas. Spheres are the most mobile form and would be derived from the upper beachface by swash and overpass processes. Inspection of Figure 13.4 shows at Clifton in some instances spheres do increase on a high seas event, viz. 12 December and on 18 October but on 27 September the spheres decrease. This suggests some balance between wave turbulence and clast forms available to be sorted and deposited.

13.9 Summary and Conclusions.

Textural gravel clast forms are the blades, discs, rods and spheres (ZINGG, 1935 cited BARRET, 1980), and the clast form parameters oblate prolate index (OPI) (DOBKINS and FOLK, 1970), and the maximum projection sphericity (MPS) (SNEED and FOLK, 1958).

Sampling Period, Seasonal Trends (spring equinox), Clast Evolution.

Table 13 3 summarises a seasonal (spring equinox) sampling period and shows the relative changes of the LW ZINGG clast forms in the longshore direction. Table 13.4 summarises the relative changes of the oblate-prolate index (OPI) and maximum projection sphericity (MPS) over the sampling period.

ZINGG FORMS	CLIFTON	TE A HALL	HAU	MARINE PARADE
Blades	increase	decrease	decrease	decrease
Discs	increase	increase	decrease	decrease
Rods	decrease	decrease	increase	decrease
Spheres	decrease	decrease	increase	increase

South ———————————→ **North**

TE A HALL Te Awanga Hall

HAU Haumoana

Table 13.3. The relative changes of ZINGG clast forms over a springs equinox (September to December 1997) at LW sample sites in southern Hawke Bay.

FORMS	CLIFTON	TE A HALL	HAU	MARINE PARADE
OPI	NC	decrease	increase	decrease
MPS	decrease	decrease	increase	increase

South ——————————→ **North**

TE A HALL Te Awanga Hall
HAU Haumoana

Table 13.4. The relative changes of the oblate-prolate index (OPI) and maximum projection sphericity (MPS) clast form parameters over a springs equinox (September to December 1997) in southern Hawke Bay. Note Clifton has no change (NC) trend.

In the longshore direction, the mean OPI changes to a more -ve value between the supply to the sink. However there are indications viz. Te Awanga that the variation of local OPI values are greater than the alongshore linear fit gradient. The MPS parameter does decrease towards the Marine Parade sink and high-energy wave environment albeit by a slight margin.

Relative Clast Forms at the Supply and Sink Sampling Sites. (Over the Sampling Period).

The differences between the supply (Clifton) and the sink (Marine Parade) clast forms (ZINGG) and sizes (Phi) indicates that generally the larger sized forms are at Clifton, and the smaller size-forms at Marine Parade (Figure 13.6). The exception is the bladed forms with some larger sizes at Marine Parade. This lends support to KUENEN's (1964) experimental findings that prolonged abrasion produces blades, however, there is no accompanying increase of bladed forms in the smaller gravel sizes. MARSHALL (1929 (a)) found the HB sizes smaller than 3.4 mm, -1.5 Phi have smaller abrasion rates. Indeed this research showed the disc population increases at the sink and in the smaller sizes relative to the supply. Gravel form stability and equilibrium within a longshore wave energy gradient appear to be the rule in southern HB. The average OPI and MPS between the supply (Clifton) and the sink (Marine Parade) (Table 13.1) shows the OPI became more -ve (more discoid) and the MPS decreased (very slightly more discoid).

Moderate and High Wave Energy Events.

In a moderate wave energy event, in the alongshore direction from supply to sink and increasing wave energy gradient, the OPI becomes more +ve at both low water (LW) and high water (HW) sample sites (Table 13.2). The MPS has no change at HW sites and a small decrease at LW sites (Table 13.2). Perhaps the most discriminating MPS change is the MPS SD (standard deviation), where at both HW and LW sites there is an alongshore decrease towards the northern higher energy.

In the moderate wave energy cross-shore direction the LW OPI is +ve and the HW OPI, (Table 13.2). LW MPS in all cases is greater than the corresponding HW sample sites, (Table 13.2).

In high-energy events (June 2000, Figure 13.9) in the cross-shore direction the extreme landward deposit clasts had +ve OPI (rodic) forms where this is anomalous. Subsequent deposition, 6 June had -ve

OPI (discoidal clasts) most landward. The MPS can be marginally greater at the overtop depositional sites (3 June), but not always, for example on 6 June the MPS is not greater at the overwash site.

Generally, the OPI parameter becomes increasingly -ve in high seas, and becomes increasingly -ve in the alongshore direction towards a higher energy gradient (clasts become more oblate, discoid). However, there is some suggestion that for a high wave energy event with overwash deposition the clasts are rodic (highly +ve OPI). The MPS does have limited sensitivity to discriminate the alongshore HB energy gradient especially at the LW. This is surprising given the active LW environment. However, the greater MPS associates with the greater energy deposits.

There are no steady longshore gradients of clast form change, however there are changes of the form parameters and sizes alongshore, especially when utilising supply (Clifton) and sink (Marine Parade) sites and averaging each site over 5 sampling dates (Figure 13.5). In this instance, towards Marine Parade, blades and discs increase and rods and spheres decrease. However, site differences are greater than the alongshore 'form' gradients. The none steady longshore gradients could relate to several factors. For example, it is possible variations of antecedent geomorphology, coupled with local grain size variations could account for these variations, as suggested by DAWE (2000) for the South Island east coast MSG coast.

The consistency of the clast forms denoted by their standard deviations with small differences between samples lends weight to the gravel stability within a longshore energy gradient.

CHAPTER 14 THE SOURCE AND SUPPLY OF TERRESTRIAL GRAVELS TO THE SOUTHERN HAWKE BAY BEACH.

14.1 Introduction.

This chapter examines the terrestrial source and supply of the gravels to the southern Hawke Bay (HB) contemporary barrier beachface.

Few studies examine the textural form characteristics of the clasts supplied to a coastal system. The Hawke Bay barrier offers an opportunity to examine the 'effects' of a gravel source and supply from three systems, firstly to the contemporary system, secondly a Pleistocene river system, and thirdly the changes of the clast forms in geological time (Plio-Pleistocene) at the source of the greywacke gravels. In this chapter sample clast forms are examined from each of the three systems to discover the clast form changes.

Methods.

The textural gravel clast parameters are their shape (size) and form. The size parameters are the moment measures of mean grain size (Phi). Size parameters apply to the river and cliff supply gravels, not to the stratigraphic (source) gravels where the only criteria were similar size requirements to compare sample gravels forms. Clast form parameters are the ZINGG categories (disc, blade, rod, and sphere; ZINGG, 1935 cited by BARRETT, 1980); the SNEED and FOLK (1958); DOBKINS and FOLK (1970) parameters (maximum projection sphericity (MPS), and the oblate-prolate index (OPI)).

14.2 Source and Supply of the Contemporary Hawke Bay Gravels.

The contemporary HB barrier gravels are dominantly greywacke and have an identifiable source the Torlesse Group greywacke facies from the inland Ruahine Ranges, (Figure 14.1). The main supplies of greywacke gravels to the modern coast are via the Tukituki River and the Cape Kidnappers cliff. It is thought clasts both near and distal from the source may have distinctive parameter differences on the basis that, (1). It is possible that the source (Ranges) clast parameters may differ through the stratigraphic column, (form differences between early and later stratigraphic clasts), and (2). The contemporary Tukituki River gravels should have clast parameter alterations in the downstream direction from the Ranges to the modern shore. (3). The contemporary supply clasts (Figure 14.1) from the Cape and the Tukituki River may alter dramatically as they cross from a fluvial and into a marine environment as suggested by MARSHALL (1929) for the Tukituki River and DOBKINS and FOLK (1970) for Tahiti-nui.

Logically clasts with the least travel distance from the Ranges, both stratigraphic and contemporary, should be different from those at the modern coast. In addition, those gravels on the beachface and those near the coast in the Tukituki River bed (with longer travel distance) should differ.

Clasts sampling took place from (A) the stratigraphic column (inland near the Ranges and at the modern coast), and (B) along the Tukituki River. The Tukituki is the only Hawke's Bay river with a continuous gravelly bed linking the Ranges to the modern coast.

Sampling at the base of the Ruahini Ranges, took place at Gull Flat and Mangleton Roads (general position 176°23'E; 39°35'S). The lithological types from which the gravel samples came (Tables 14.1a and 14.1b) are Mid to Late Pliocene, Waitotaran Stage, mostly coquina limestones, but also marl, which that contain greywacke clasts from the emergent Ruahini Ranges. Sampling also took place at

Mangleton Road at a Late Pleistocene, Hawera Stage, conglomerate. This conglomerate is a fluvial deposit and stratigraphically comparable to the Cape Kidnappers, Castlecliffian conglomerates that were also sampled. Two Tukituki samples came from select distances upstream from the inlet (Tables 14.2a and 14.2b).

14.3 Inland Source Gravels (Near the Ranges).

The inland Pliocene gravels, sampled at Gull Flat Road (A in Figure 14.1), and Mangleton Road (B and C in Figure 14.1) represent clasts eroded from the nearby emerging Ruahini Ranges with a relatively short transport distance, less than 5 km, to their deposition site. Therefore, clast modification by transport abrasion should be relatively small. However, these Pliocene (Waitotaran) clasts are coastal marine deposits (lamina bedding and marine Mollusca) and coastal process modifications are expected.

These Pliocene clasts should have parameters quite different from those gravels that have transported a greater distance (some 100 km) in a fluvial transporting environment to the modern coast. In HB, it is possible to check this hypothesis from both the stratigraphic record and from the modern Tukituki River (Section 14.6). As a check the sampling of a comparable Late Pleistocene stratigraphic unit took place. Firstly at the Mangleton Road, Late Pleistocene, Hawera terraces, as the near Ranges source fluvial gravels, (C in Figure 14.1) and secondly at the Cape Kidnappers, Late Pleistocene, Castlecliffian as the distal fluvial gravels (D in Figure 14.1). Most of the Cape Kidnappers Castlecliffian conglomeratics are fluvial deposition strata but become marine towards the upper beds exposed at Clifton.

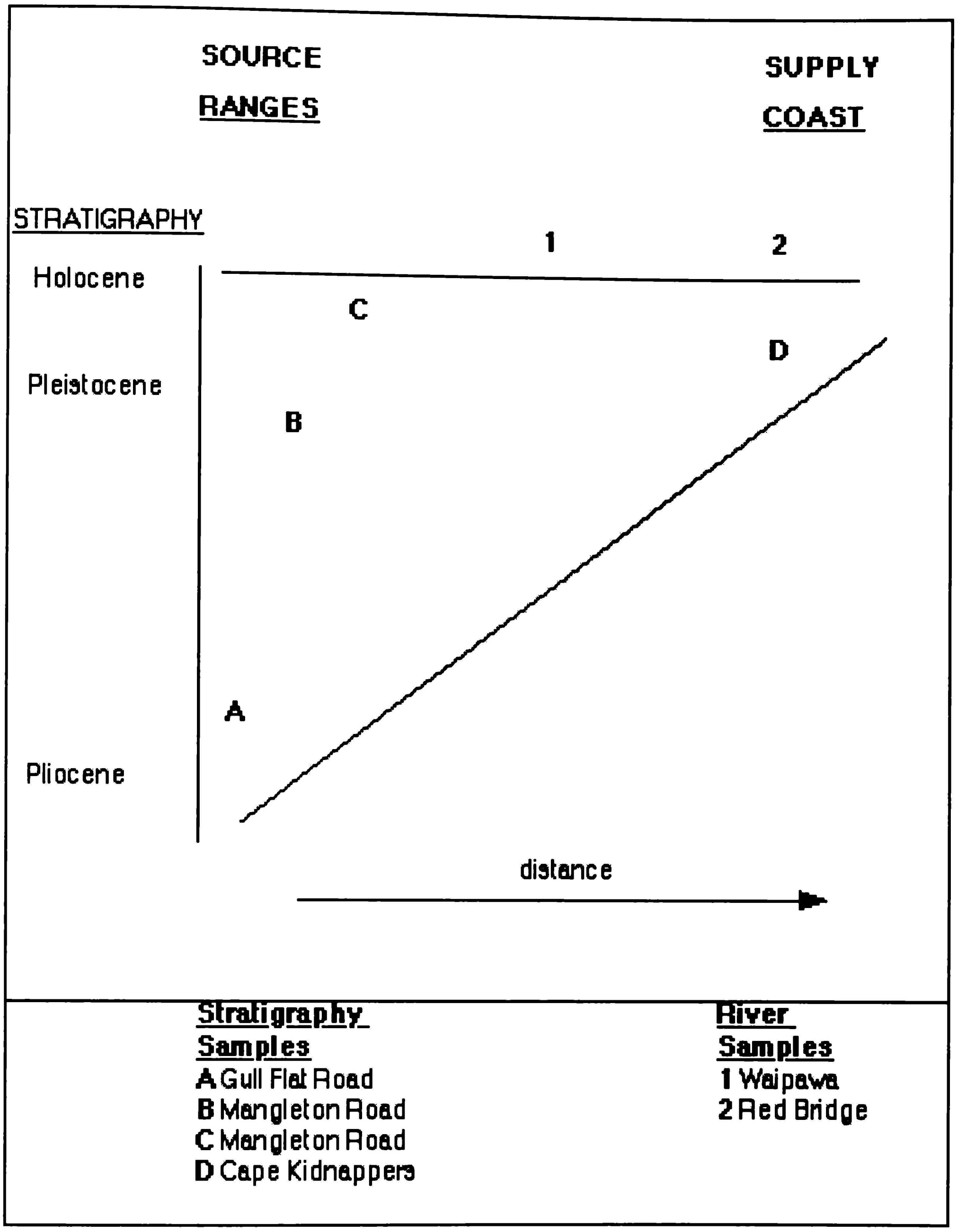


Figure 14.1 Diagram indicating the sampling concept to model the gravel form changes. These are (A) the stratigraphic samples from (1) near the source (Ranges) and (2) at the modern coast and (B) those in the modern river (the Tukituki River) link between the Ranges and near to the modern coast.

14.4 Results (the Inland Clasts).

The ZINGG forms show frequency changes where disc forms increase towards the Late Pleistocene whilst the rod percentages decrease and the percentage of blades and spheres have a slight decrease, (Table 14.1a).

Both the OPI and the MPS parameter values reduce towards the top of the stratigraphic column with clasts becoming more oblate (bladed), and with MPS the clasts become less compact (spherical) and more flat (discoid). Table 14.1b

Stratigraphy	Lithology	d50 (mm)	Blade	Discs	Rod	Spheres	N
Pleistocene							
Late	Conglom	24.3	9	41	20	30	1
Mid	Conglom	14.0	5	32	29	34	1
Pliocene							
Late	Marl	6.5	8	24	36	32	1
Late	Coquina	6.1	19	25	25	31	1
Mid	Coquina	16.9	3	27	25	45	1

N = number of samples.

Late Pleistocene conglomeratics, Hawera Terrace, Mangleton Road. (Figure 14.1 labeled C)
Mid Pleistocene, conglomerate is Castlecliffian (KAMP, 1978), Cape Kidnappers. (Figure 14.1 labeled D)
Late Pliocene coquina samples are from Mangleton Road. (Figure 14.1 labeled B)
Late Pliocene marl and Mid Pliocene coquina are from Gull Flat Road. (Figure 14.1 labeled A)

Table 14.1a. The ZINGG form counts (%) for selected Pliocene-Pleistocene clasts.

Stratigraphy	Lithology	d50 (mm)	OPI	MPS	N
Pleistocene					
Late	Conglom	24.3	0.86	0.66	1
Mid	Conglom	14.0	1.2	0.69	1
Pliocene					
Late	Marl	6.5	2.12	0.71	1
Late	Coquina	6.1	1.45	0.69	1
Mid	Coquina	16.9	2.01	0.73	1

N=number of samples.

Table 14.1b. Summary of the OPI (Oblate Prolate Index) and the MPS (Maximum Projection Sphericity or effective settling velocity) for the stratigraphic samples.

14.5 Summary, the Inland Source Gravels.

Ignoring any influence of the size effects on the clast forms (BLUCK, 1967) the source clast form parameters do have stratigraphic trends in a younging sense. Firstly the ZINGG forms. Initially (Mid to Late Pliocene) the clasts are more spherical with near equal proportions of discs and rods. In later geological time (Pleistocene) the greywacke clast forms become more discoidal. Secondly the OPI and MPS forms. The OPI parameter rod (oblate) forms decrease and the bladed (oblate) forms increase. The MPS parameter shows the clasts become increasingly more discoid over the same time period.

The Pliocene depositional environment was probably shallow water marine whereas the Pleistocene environment was fluvial (ignoring the Cape Kidnappers marine Late Pleistocene). The disc form increase may be a feature of greywacke material transporting further east in a fluvial environment, or more likely a factor of some other lithologic control, for example tectonic stress relief of compressional jointing.

14.6 Contemporary River Clasts (the Tukituki River valley) the Source-Supply Link.

The Tukituki River bed samples, 1988 (WHITE, 1992) and in 1998, represent an upper (at the Tukituki and Waipawa rivers confluence) and a lower (Red Bridge) Tukituki River gravel bed. The sample locations are Waipawa (V22 616337) and Red Bridge (V22 466580).

Table 14.2a summarises the clast form changes between 1988 and 1998. From Table 13.2a, the disc forms are the most frequent at both Waipawa and Red Bridge in 1988 and 1998. Table 14.2b summarises the OPI and MPS parameter changes. The OPI indicates bladed forms with a trend towards more rodic forms in 1998. The MPS parameter suggests very little change downstream, within 0.62 to 0.64 from 1988 to 1998.

Site	d50 (mm)	Blade	Disc	Rod	Sphere	N
<u>1988</u>						
Waipawa	21.2	19	47	20	14	1
Red Bridge	27.9	15	49	11	25	1
<u>1998</u>						
Waipawa	27.6	7	46	33	14	1
Red Bridge	28.7	27	39	27	7	1

N=number of samples.

(sample sites: Waipawa (V22 616337); Red Bridge ([V22 466580).

Table 14.2a. The ZINGG forms (%) for the Tukituki River greywacke clast supply. The distances from the Tukituki inlet to Red Bridge is 16 km, and to Waipawa is 70 km.

14.7 Contemporary Supply Gravels at the Coast.

The contemporary gravel supplies to the coast include (i) Cape Kidnappers (sample site W21 552653) and (ii) the Tukituki River (Red Bridge as the most river modified before beachface deposition), (iii) those incorporated within the MSG barrier, and (iv) clasts from the nearshore. Sampling those incorporated within the barrier did not directly take place. Sampling the nearshore, gravels did not take place but they are easily identifiable by seaweed root-clasp structures and coatings of Bryozoa (white and occasionally pink).

The Tukituki River gravel clast parameters from the lower Tukituki River at Red Bridge (Section 14.6, Tables 14.2a and 14.2b) (1988 and 1998) are averaged for the summary (Section 14.8, Table 14.4).

Site/Date	d50 (mm)	OPI	MPS	N
1988				
Waipawa	21.2	0.04	0.62	1
Red Bridge	27.9	-1.01	0.63	1
1998				
Waipawa	27.6	0.33	0.64	1
Red Bridge	28.7	0.44	0.62	1

N=number of samples

Table 14.2b. Summary of the OPI and MPS parameters for the Tukituki River gravel supply. The distances from the Tukituki inlet to Red Bridge is 16 km, and to Waipawa 70 km.

Sample	d50 (mm)	Blade	Disc	Rod	Sphere	N
(a) gully washout	13.9	9	41	16	34	1
(b) low water	15.6	9	42	24	25	1

(a) 6 Nov 1997 Sample sites (W21 552653)

(b) 27 Jan 1998

Table 14.3a. The ZINGG clast form counts (%) for the Cape Kidnappers supply.

Tables 14.3a and 14.3b summarise the Cape supply gravels represented by two samples. Both were colluvium from the foot of the cliffs with one from a steep sided gully washout fan above the storm high water and the second from a low water detached cusp. Table 14.3a shows ZINGG discoidal forms dominate both samples, spherical forms are also numerous especially at the gully. The OPI and MPS clast parameters (Table 14.3b) show the OPI varies between gully supply discoidal (oblate) forms and low water rod (prolate) forms, whilst the MPS indicates a very small trend to more discoidal forms at the low water beachface.

Sample	d50 (mm)	OPI	MPS	N
gully washout (a)	13.9	-0.5	0.68	1
low water (b)	15.6	0.47	0.67	1

(a) 6 Nov 1997

(b) 27 Jan 1998

Table 14.3b. Cape Kidnappers supply gravels, oblate prolate index (OPI) and maximum projection sphericity (MPS).

	Tukituki River		Cape Kidnappers cliff	
Mz (Phi)	1988	-4.54	1997	-3.68
	1998	-4.58	1998	-3.74
Sorting	1988	0.86	1997	0.58
	1998	0.91	1998	0.81
Skewness	1988	-0.28	1997	-0.25
	1998	-0.06	1998	-0.03

Table 14.3c. Contemporary Hawke Bay barrier supply gravels, mean grain size (Phi),sorting (Phi), and skewness. Supply gravels are the lower Tukituki River and Cape Kidnappers cliff colluvium.

Viewing Section 14.3, clasts in a fluvial system before entering a marine environment have greater value MPS and the greatest +ve OPI. Interestingly the palaeleofluvial Cape Kidnappers conglomerates have closer affinity to the ‘typical fluvial facies’ (DOBKINS and FOLK, 1970) than those from the modern Tukituki River. Table 10.3c summarises the Cape Kidnappers cliffs and Red Bridge clast grain size parameters.

14.8 Summary of Supply (Cape Kidnappers and Tukituki River) Clast Parameters.

The average clast forms (Table 14.4) show the supply of discs and the rods to the beach have about equal proportions. The Cape supplies fewer ZINGG form blades and more spherical clasts compared to the Tukituki River. OPI averages for the supply clasts differ with the Red Bridge clasts more oblate (or discoidal) than the Cape gravels, which tend towards prolate (rod) forms. Cape gravel MPS averages have a greater MPS, or a greater spherical form, whereas the River clasts have a lower MPS, or tending to a discoidal form.

Clast Form Parameter	Supply	
	River (Red Bridge)	Cliff Cape Kidnappers
Blades	21	9
Discs	44	41
Rods	19	20
Sphere	16	29
OPI	-0.28	-0.02
MPS	0.63	0.67

OPI = Oblate Prolate Index
MPS = Maximum Projection Sphericity

Table 14.4. The average supply clast form parameters for the lower Tukituki River (Red Bridge), and the Cape Kidnappers cliffs colluvium.

14.9 Discussion, Clast Supply Parameters.

Both the Cape cliff colluvium and lower Tukituki (Red Bridge) supply mostly discoidal forms (ZINGG, OPI). The Cape gravels have the greatest range of parameters, for example the OPI parameter and mean grain size (Table 14.3b). OPI and MPS parameters suggest the cliff supply material has mostly oblate spherical clast forms. Samples from the Cape cliff and the Tukituki River had different mean clast sizes (Tables 14.3a and 14.3b, Tukituki > Cliff). The difference of mean grain size could influence the clast parameters (see, for example, the debate of the most useful parameters BARTHOLOMA, et al., 1998), given that ZINGG form measurement biases forms towards rods when using the intermediate axis length as a size measure (WILLIAMS and CALDWELL, 1988).

Tukituki River clasts have very small difference of clast size statistic parameters given a 10 y gap between sampling. Cape cliff clasts have a greater variation of statistical parameters but this is expected given the morphogenesis of the sampling sites (gully colluvium and low water cusp horn). Indeed both the Cape cliff and Tukituki River inject the maximum quantity supply as a chaotic sediment pulse, as cliff fall or gully washout, or as river flood discharge and having a maximum randomness.

Clast form characteristics suggest early clast sorting by swash at the Cape Kidnapper's beach. The low water detached cusp sample falls within the DOBKINS and FOLK (1970) suggested OPI and MPS with less oblate more +ve values (rods) and greater MPS (tending too spherical) thus differentiating between low water and upper beachface (fluvial) clast forms. Or, a 'typical' low energy step toe Chapter 8 Figures 8.4 and 8.5). Upper beachface clasts found on Tahiti-Nui suggest the beach crests typically have -ve OPI and low MPS relative to the lower beachface (Chapter 8, Figure 8.5) (DOBKINS and FOLK, 1970).

Gully clast form parameters do not completely fit the DOBKINS and FOLK (1970) model. The Cape gully sample does have -ve OPI, however the MPS is not less than the low water sample. The process here is one of isolation. Gully clasts remain isolated from daily swash active sorting of clasts. The gully washout fan has a high spherical clast content and this would agree with BLUCK (1982) who found ZINGG form spheres to progress downstream, so that some clast sorting may be taking place within the narrow and steeply inclined gullies. The gully sample suggests reworking of clasts forms may be taking place with less frequent mobilisation and associated clast form sorting.

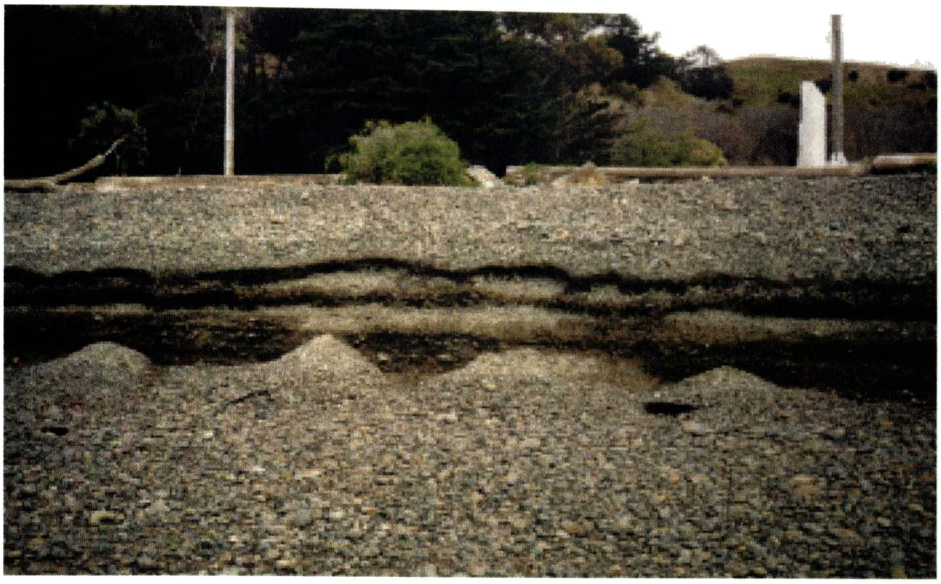
The Cape Kidnappers beach morphology is narrow, backed by cliffs (a fringing barrier), whereas the contemporary barrier beach crest to the north is free to migrate. Cape Kidnappers beaches have colluvium, the chaotic poorly sorted, non-stratified cliff fall material observed as scree (dry fall) and fan (gully fluvial washout) morphologies. Cape Kidnappers cliff supplies can contain up to an estimated 10,000 m3 in a single cliff fall, whilst gully washout have an estimated 10's m^3. The low water sample indicates the early reworking of clast forms available as supply material for the HB barrier.

At the Cape low water, and the Clifton beachface the sedimentary gravel sizes must sort rapidly across the surface and can be observed as strata, composed of well sorted gravels within the beachface in terrace cuts (Figure 14.2).

As the coast is approached, the river clasts assume sorting characteristics that generally have well defined clast parameters (see Chapter 8 for the 'type' gravel characteristics). The Tukituki River gravels do not fit the 'type' river gravels. For example, the MPS does not have the greatest value and the OPI does not have the greatest +ve values. The maximum quantitative forms are not spheres and spheres do not occur in greater frequency than discs. Indeed the reverse is true where discs have a greater frequency than the spherical forms.

However the river flood sediments arrive at the coast as a chaotic supply with most passing into the inshore and subsequent post storm sorting across the inshore, and at the beachface size form sorting may be fairly rapid.

MARSHALL (1929) noted the differences of gravel form (flatness) between the Tukituki River bed, near the river inlet and downdrift, along the beach (to the north) at Waitangi (near Awatoto). MARSHALL (1929) describes the Tukituki River gravels one mile (1.6 km) upstream from the inlet as rounded (large gravel sizes 12.7 mm to 6.3 mm). At the inlet, the beach gravels are described as "all of the large pebbles are more or less flattened" and at Waitangi pebble flattening "was far more pronounced". MARSHALL (1929) proposed wave swash action abrasion processes, firstly where the wash of fine material (sands) acting on large pebbles flattened them and secondly the flat wearing of pebbles perhaps partially by movement over pebbles in the beachface (no sliding specifically mentioned).



(John White print 7)

Figure 14.2. Clifton 17 October 1999. In background fossil cliffs (5,000 y BP, LEWIS, 1971). Beachface strata as a result of sorting. At the base of the terrace cut imbricated large and fine gravels and sands. Intermediate layers of very well sorted gravels-sands. Top gravels as truncated cusp horns spilling onto beach.

Observation of the HB beachface clasts suggests other abrasion processes. Clasts from the Cape invariably have an iron oxide coating. This coating does not wear uniformly across the clast surface. Discs for example have outer edge wearing, whilst the iron oxide coating remains over the flattened (short axis) surfaces. This edge abrasion suggests two processes. Firstly the discs roll, and sliding in not a major abrasion component. Secondly, the disc clast lays flat on a sandy beachface and the sand in the swash abrades the clast edges. The rolling of clasts as a likely process is evident by other clast forms. For example, rods have selective removal of the iron oxide coating from the (long axis) ends of the rod form.

14.10 Conclusions.

1. Inland gravels from the Ranges have clast form changes from the Mid Pliocene through to the Late Pleistocene, and this is true for both marine (Pliocene) and fluvial (Pleistocene) environments. As the gravel beds become younger, so the percentage of the disc forms increases whilst the rods decrease; bladed clasts frequency remains near constant and spheres show a slight decrease. However, it does appear that discoid forms are a frequent form through the stratigraphic column, and this suggests some process other than swash abrasion is an agent producing clast form. In this instance an additional greywacke jointing pattern is important. Fissile splitting of the greywacke is a major contributor to the form of the HB clast forms.
2. Discs dominate the contemporary Tukituki River gravel supply material. Other clast forms vary over the sampling interval (1988 and 1998), but generally the rank order is discs > rods > spheres > blades.

3). Conclusions 1 and 2 above indicate discs are the dominant form supplied to the HB barrier, and before abrasion takes place at the beachface. Pebbles are often reported to become flat (discoidal) upon reaching a coast (MARSHALL, 1929; DOBKINS and FOLK, 1970) but Hawke Bay does not conform to this generalisation.

4). MPS and OPI clast form parameters are more variable in the inland gravel samples than the contemporary river samples.

5). The supply gravels from Cape Kidnappers and the lower Tukituki River (Red Bridge) are disc dominant. More blades are in the river supply than from the Cape, whereas the Cape supplies more spheres. However, the Cape gravels have a greater textural size range than the Tukituki. Tukituki River gravels are better sorted (by value and by range of values) than the Cape gravels; skewness for both supplies is symmetrical to coarse skewed. These size parameters would suggest the modern Tukituki River is a more energetic system than that which deposited the Cape Kidnappers conglomerates. For example SAHU (1964) suggests negative skewness can result when the velocity of the depositing agent was greater than average (see Section 8.3 for discussion on the low water textural parameters).

CHAPTER 15 CONCLUSIONS.

15.1 The Major Findings of the Thesis.

- The Hawke Bay barrier landform has two main morphological components. To seaward is the modern single crest transgressive ridge and to landward the antecedent multicrest 'ridge'. The single ridge is either a stand alone feature, for example between Clifton and Te Awanga, or has welded onto the antecedent ridge, for example between Te Awanga and Haumoana. The stand alone single ridge is transgressive since it migrates landward by rollover processes involving overwash sediment deposition. Where the single ridge has welded onto the antecedent ridge, the gravels can overwash the seaward crest. Further, where the single crest has welded, the beachface process is one of cannibalistic 'erosion' of the antecedent ridge, hence the landward translation of the coast between Te Awanga and Haumoana.

- The breaking wave types are distinctive for 'erosional' and accretional events. Erosional waves are plunging at high tide and spilling at low tide. Accretional waves are either 'foaming plungers' or surgers that can be collapsing. The type of wave breaker is a function of the beachface morphology.

- The beachface 'cycles' through a morphological range when undergoing 'erosion' and accretion events. The upper beachface High Water ridge can erode by sapping where the run-up waters transport material down the beachface in the backwash. It is also possible that some of the beachface material is transported further up the beachface by the run-up. Some material transported in the backwash deposits at the step position and forms a 'fan'. The backwash also retards the incident wave so that the breaker type changes from plunging to a 'foaming plunger'. As the fan height increases the backwash waters flow laterally and scouring forms a 'hole' at the step position. Hence, alongshore an alternating series of 'holes' and 'fans' forms. The breaking waves now take on distinctive breaker types as foaming plungers over the fans and surgers that can collapse over the holes. The surgers transport the coarser gravel sizes up the beachface as a saltating population, with some gravels transported as projectiles through the air. These coarser gravels deposit opposite the holes and proto cusps form.

- The cross-shore transverse profiles give some measure of the morphodynamics as a 'cyclic' series of responses. Profiles taken at monthly intervals demonstrate the beachface can either 'rotate', or, 'non-rotate' about the Mean Sea Level position. Rotation is measured as the High Water ridge accretion and the lower beachface platform erosion, followed by the High Water ridge erosion and the platform accretion. Non-rotation is no change at the lower beachface and accretion by welding sediment onto the front of the High Water ridge.

- The beachface Profile Shape Index shows all beaches have a 'restricted' geometric variation. Sand beaches have a profile shape that can vary from concave up, to linear, to convex up. The Hawke Bay beachface shapes are restricted to concave up and linear.

- The best least squares polynomial fit between select parameters is for the change of sediment volume (dQ) and the breaking wave steepness B_s, with R = 55%.

- The Hawke Bay beaches had accretional and depositional 'events' that can be related to the incident breaking wave steepness (B_s). When the wave steepness is greater than 0.026 to 0.03, the beachface is accretional. Further, WRIGHT et al. (1979) found beaches accrete when the surf scaling parameter ε decreases in value. In Hawke Bay, the Te Awanga Hall beach accretes when ε increases.

- The Iribarren Number ($\xi < 1.12$) and the surf scaling parameter ($\varepsilon \approx 2.5$) suggest the beachfaces are reflective and are run-up dominated.

- The gravel size parameters have a seasonal gradient, where the parameters change over time. In cases, the parameter changes appear seasonal, and in others not so, suggesting some other factor(s) are perhaps present.

- Generally, at all sites, the winter and summer gravel populations differ. Winter gravels typically have coarser sizes, better sorting and have (coarse) -ve skewness, whilst the summer gravel populations are finer, more poorly sorted and have (finer) +ve skewness.

- The gravel size parameters were placed into a McLAREN model (McLAREN and BOWLES, 1985) and over a 'season' the parameters attained a common state on two occasions. Firstly, after a prolonged low wave energy period, the state was H (Finer, Poorly sorted and Positively skewed). Secondly, for each of three high-energy events ($H_b > 1.0$ m) the Te Awanga Hall Low Water gravels attained the state D (F, P, -ve). In addition, state D was the most frequently attained state at all sites in high seas.

- An alongshore energy gradient occurs between Clifton and Marine Parade, and the textural anaysis results shows that the Clifton gravels are coarser, more poorly sorted and are more positive skewed. However, the textural size parameter variations at a site can be greater than the alongshore energy gradient changes.

- Gravels were also sampled in a moderate high seas event when the wave steepness B_s increased from 0.019 to 0.035. At two sites Clifton, and Te Awanga Hall the HW ridge underwent sap erosion of an antecedent High Water ridge, but Marine Parade was marked by an overtop deposition at the High Water position. Over this event, the supply site beachface slopes decreased from 0.1 to 0.09, and the sink beachface slope increased from 0.09 to 0.1. Results show the average gravel sizes were coarser at the HW than at the low water (LW) positions. Sorting changes were generally negligible in the cross-shore direction. Skewness changes in the cross-shore were negligible at the low-energy sites and at the high-energy site the LW positions were slightly more –ve skewed. In the alongshore gradient towards Marine Parade the mean grain sizes became finer at both the HW and LW sites, sorting became better and the skewness increasingly negative, equivalent to the McLAREN state (A or a summer transport state). Clifton was state (B), Coarser, Poorly sorted, Positive skewness. The Te Awanga Hall was an exception, as an example of a local effect that can 'disrupt' the wider geographical trend(s).

- At the Te Awanga Hall site a HW ridge accreted over a high wave energy event. The wave steepness B_s increased from 0.019 to 0.037 over 5 days. Two sets of gravel samples were collected from the same cross-shore positions. The first set was an overwash population, and the second set was an overtop population. Gravels transported landwards as overwash at an accumulating HW ridge with a $B_s = 0.0451$, and Iribarren number $\xi = 0.796$. Overwash gravels were coarser, better sorted and increasingly +ve skewed to landward, equivalent to a McLAREN model (McLAREN and BOWLES, 1985) state G (a winter transport state, and a decreasing energy state). The Iribarren number became $\xi = 1.398$, and the beachface slope decreased from 0.1 to 0.09. The depositional overtop gravels split into two populations, firstly a landward population and secondly a welded to seaward at the High Water ridge population. The seaward population was coarser, with improved sorting and +ve skewness, or a winter transport, decreasing energy, state G population. Therefore the landward transport populations have distinctive positive skewness, are coarse and well sorted.

- Gravel forms have a 'seasonal' change, however like the sizes the indications are that other factor(s) are apparent since a form does not increase or decrease as summer – winter seasons change, but can continue to increase, or decrease.

- Over a season the gravel forms, when averaged at each site, and in the alongshore direction from Clifton to Marine Parade show the blades and discs increase and the spheres and rods decrease. However, the individual intervening site variations are greater than the alongshore 'form' gradients. Blades increase in the larger sizes. In a moderate energy seas the Oblate Prolate Index (OPI) is more positive (become rodic) at low water sites and more negative at high water sites. In a high energy seas event the OPI initial overwash became more positive to landward. Subsequent overtop deposits were negative OPI. Therefore, the high seas depositional sequence is initially rods, followed by discs.

- Gravels are mostly greywacke and have an established source and two recognisable contemporary supplies. The source of the HB coastal greywacke gravels is the inland Jurassic Ranges. In geological time, pulses of eroded gravels have transported to the east, a later pulse formed the Late Pleistocene Cape Kidnappers conglomerates, mostly fluvial deposits with late shallow marine. These Cape conglomerates are the main contemporary supply observable as cliff fall material along the base of the cliffs. The second supply is the modern Tukituki River the only link that transports gravels from the eroding Ranges to the coast. The river supply is infrequent and depends upon river flood discharge to transport gravels to the coast, whereas the cliff material supply is intermittently continuous.

- The dominant clast form characterising the HB barrier, is the disc gravel forms supplied to the modern coast are mostly discs. Gravels sampled from the stratigraphic column (Late Pliocene and Early Pleistocene) adjacent to the source found the earliest clasts were mostly spherical, with the disc forms becoming dominant in an Early Pleistocene fluvial environment. The supply gravels released from the Cape Kidnappers cliff also undergo fissile splitting that induces a discoidal form. The Tukituki River gravels are mostly discs that may also be a product of fissile splitting. These results suggest there is a tectonic signature, which predetermines the clast form, and one expression of this is the fissile splitting.

15.2 Future Research.

1. Cross spectral analysis of the time series data. This could have many applications. An example is the placement of renourishment material for best effect, viz. the upper or lower beachface, and the most effective placement time(s). Extending the parameter records and cross relating in time series would undoubtedly give a better understanding of barrier behavior and some insight into the unraveling evolution.

2. Discover what is the structure of the barrier environs. This would entail two investigative methods. Firstly, sub-bottom profiling and vibro-coring across the inshore. This would discover (i) the vestige gravels across the inshore resulting from storm erosion, and (ii) possibly past barrier positions. The inshore may also prove a source or supply of gravels for the modern barrier. Secondly, the use of ground penetrating radar across the barrier to determine the structure of the barrier and the nature of the backbarrier, for example are there previous transgressive gravelly sheets at depth? This could also indicate the transgressive behavior of the barrier across bedrock as opposed to across muds.

3. Side-scan sonar and map the inshore substrate for sedimentary bedforms and sediment textures. This approach could also be useful for determining the quantities of gravel discharged from the Tukituki and Maraetotora Rivers and any resulting changes to the immediate inshore seabed.

4. Collect good quality wave and current data over a long period of time to include 'normal' and high wave energy events. Of great interest would be the reflected waves and the infragravity waves and edge wave signals. The sea water level to determine changes.

5. Gravel tracers (i) to indicate where on particular clast forms the wear takes place, and from this modes of transport. (ii) the transfer of the gravel sizes across the step between the HW ridge and the inshore, and (iii) the form of these transfer clasts. What proportions pass into storage inshore, or at depth within the beachface.

Current Research Needs.

Locally Hawke Bay requires a coordinated acquisition of suitable databases ranging from the physical (geology, geomorphology, hydrographic, and hydrodynamic) to the biological and ecological distributions for coastal management. As a research area there is much opportunity, examples are the internal barrier structures within the contemporary transgressive single crest, to locating the gravels in the inshore. The relative ages of the antecedent multi-crested barrier and the modern single crested ridge are required. There is an urgent need to obtain reliable data of the relative levels of the sea and the hinterland, not only for the expected sea level rise but in Hawkes Bay there are at least two tectonic scales, firstly the instantaneous fault deformation, and secondly the slower warping of the folds (CARTER and LEWIS, 1976). On a world scale, the transport of gravel across the inshore to barrier backbeach is not well defined.

15.3 Coastal Management.

The findings of this thesis suggest that considerable research is required expressly aimed at the HB barrier. In addition, research needs to be pursued prior to the expansion of management and plans related to the coast. Generally for New Zealand, the field research of the geological and hydrodynamic interface would undoubtedly be of great benefit for coastal environment management.

15.4Ubiquitous conclusion.

There is an urgent need in New Zealand for long term, for example 30 y, data gathering in a systematic and rational scale.

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Appendices

Appendix 1

The Hawke Bay Coastal Geology

THE HAWKE BAY COASTAL GEOLOGY

1.0 Introduction.

Traditionally the Hawke Bay (HB) coastal geology is divided into a terrestrial and a marine part, for example there are two Bulletin publications for the contemporary coastal geology, the terrestrial part (KINGMA, 1971) and the marine part (PANTIN, 1966). The HB marine geology is described by PANTIN (1966) as reworked sediments with textures ranging from inshore wave beveled platform gravels to nearshore sands and muds to shelf muds.

The terrestrial coastal geology is well defined by two resistant rock headlands that out crop as cliffs some +100 m (MSL) at the coast KINGMA (1971). These headlands are the Late Pleistocene (Castlecliffian) Cape Kidnappers and the Early Pleistocene (Nukumaruan) Scinde Island. Between these promontories are the Holocene sediments (Figure 1) characterised by the contemporary narrow gravel fringing barrier beach system, a most significant geological and morphodynamic structure and major example for the east coast of the North Island.

This appendix reviews two broad aspects of the coastal geology via literature review and drawings of bores both inshore and onshore and a set of inshore cores. The two aspects are the near surface geology and the far surface geology.

The first broad aspect concerns the near surface geology of the terrestrial and marine environments, to formulate a basement geology since this is important in the evolution of a barrier system (FORBES, et al., 1995). The basement is used here to describe the barrier foundation since what the barrier rests upon may have some mesoscale effect. The HB has undergone eustatic sea level (SL) fluctuations characterised by wave planed surfaces (LEWIS, 1973). The most recent surface is characterised by radiocarbon dates with many at some 7,000 y BP. This surface is chosen as a basement, since it has expression both inland and seaward of the contemporary barrier. The first question to be explored is:-

1). The nature of the basement, the near surface stratigraphy and sediments from cores and bores adjacent to the contemporary barrier, and what does the modern barrier rest upon?

The second aspect in this chapter reviews the far surface geological information to illuminate the possibility of previous barriers and the modern barrier genesis. This explores the geology greater than 7,000 y BP to the limit of bore hole depth. The next questions view:-

2). The possibility of previous gravel barriers, the bores at depth.

The contemporary barrier sediments contain marine shell material and carbonised wood, with the latter derived from the Cape Kidnappers, Castlecliffian. It is considered that previous barrier sediments would also contain similar materials. This would assist in delineating any previous barrier migration and forecasting further barrier positions. From the deepest bore hole logs both near the coast and inland are there any indications of previous gravel barrier(s)?

3). The genesis of the HB barrier from the bores at depth, for indication of availability of gravel supply, and have these altered?

2.0 Marine Geology of Hawke Bay.

The contemporary HB coastal stratigraphy is dominated by glacioeustatic lithologies (BEU and EDWARDS, 1984; NEWNHAM, et al., 1999), but superimposed are the tectonic signatures ranging from the smaller spatial scale co seismic stratigraphic events to the larger spatial scale geological structural warping of the region.

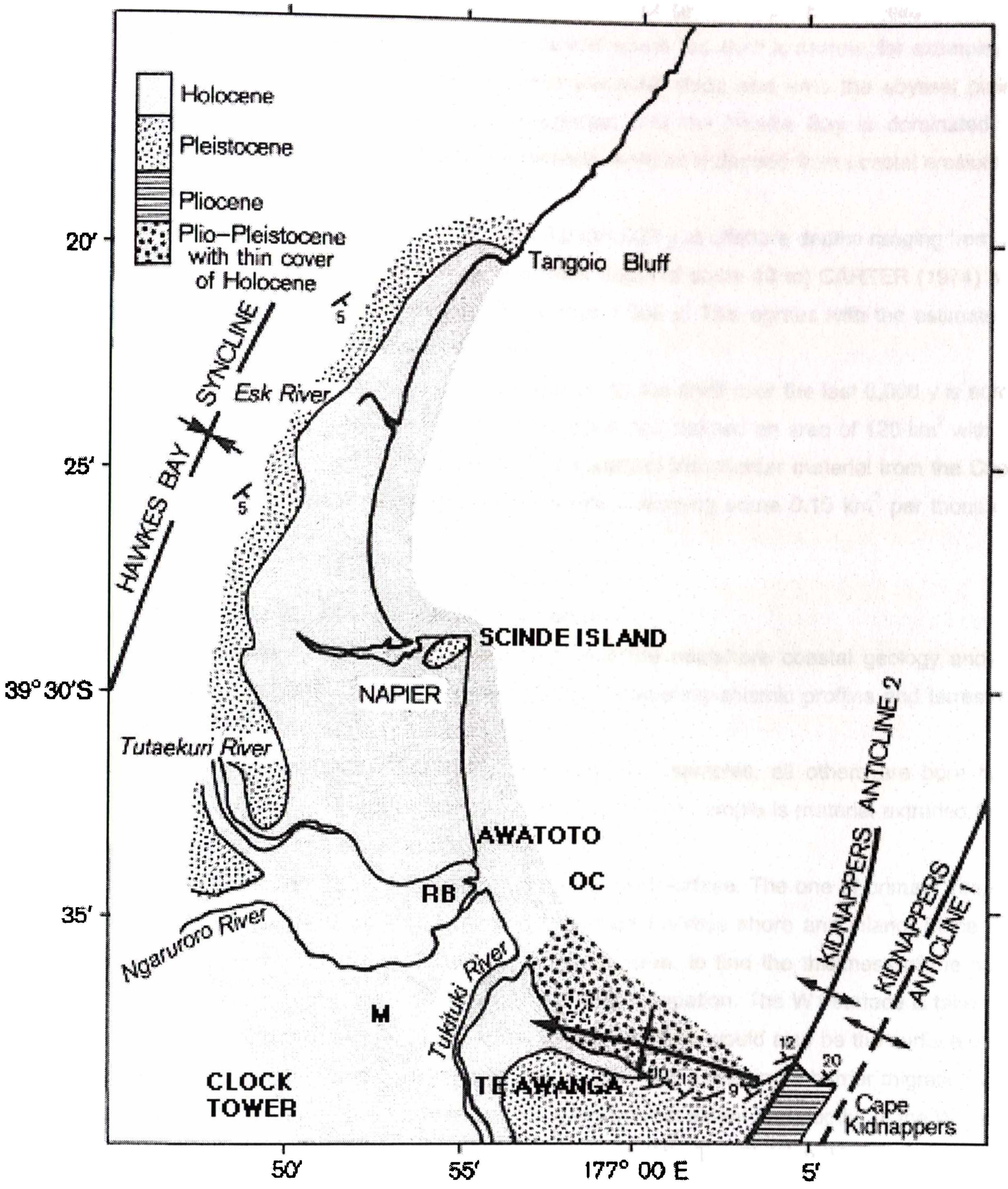
2.1 The Hawke Bay Shelf Near Surface Stratigraphy and Sediments.

The terrestrial rocks of the Cretaceous and Tertiary are unconformable overlain by Pleistocene sediments (CARTER, 1975) and these in turn by unconformable Holocene - including the contemporary sediments (LEWIS, 1973). These rocks evidently extend from the land and out across the nearshore sea bed. Indeed in southern HB off Cape Kidnappers the nearshore out cropping rocks "are considered" to be the same age as the onshore Middle Quaternary (Castlecliffian) and Pliocene rocks and all have a similar westward dip (LEWIS, 1973; CARTER and LEWIS, 1976), Figure 1.

During the last glacial period (Otira) the nearshore inner part of the Hawke Bay shelf would have been beveled twice by the process of wave planation. The first beveling as the SL began to fall at the onset of the Otira and again later as the SL began to rise to near its present level as the ice sheets retreated. Between these two beveling the exposed plain would erode sub aerially with the HB rivers discharging some 20 km to 30 km further to the east to reach the coast now far below the modern SL (LEWIS, 1973).

In HB the Otira maximum induced a low SL still stand at "about 110 m below present sea level" (LEWIS, 1973). This particular depth is chosen where the break of slope abruptly increases seaward. This maximum is taken as equivalent to the European Würm or the New Zealand Middle Otiran (glaciation; MOI 2) to Middle Aranuian (interglacial, MOI 1). (MOI = marine oxygen isotope). LEWIS (1973) recognises this SL low stand beveled surface as an unconformity, termed W1, from seismic profiles. This W1 surface has a time horizon seaward base at 20,000 y BP and a landward base at 5,000 y BP. Resting upon this (W1) unconformity are the Late Quaternary and the most recent Holocene beds forming a post-glacial depositional prism.

These unconformable sedimentary sequences are called the Acheron by LEWIS (1973) and "consist of a thin diachronous sand layer and overlying mud with shells and volcanic ash" accumulated in the last 20,000 y BP as the SL began to rise. The Acheron sediment wedge is perhaps very complete in that it has not been beveled to any great extent although PANTIN (1966) dates a pebble mud relict surface in central Hawke Bay at 8,000 y BP that separates the Early and Late Acheron (LEWIS, 1973).



Locations of coastal and inland cores and bores.

OC = Off Clive
RB = Rail Bridge
M = Mangateretere

Figure 1. The coastal geology for Hawke Bay (CARTER and LEWIS, 1978).

In the subsequent SL rise the coastal plain sediments will have reworked so that some of the present day sea floor sands and gravels are relict in nature and that these relict deposits have a similar composition to their modern counterparts (CARTER, 1975). These gravels are mostly greywacke and are known to be resistant to abrasion (HEMMINGSEN, 2000) and therefore more likely to persist in time.

From the Early Acheron to the present the supply of sediment to the HB shelf has been and remains considerable. These sediments are mostly muds and where the shelf is narrow, for example, to the south of Cape Kidnappers the muds extend across the shelf slope and onto the abyssal plains (CARTER, 1975). LEWIS and KOHN (1973) has suggested that the Hawke Bay is dominated by terrigenous detritus and only a few percent of the sedimentary material is derived from coastal erosion so that each deposit is rapidly buried.

The rate of burial is estimated at some 1.5 m to 3.0 m/1,000 y at offshore depths ranging from 30 m to 150 m (LEWIS, 1973). In the inshore (an inshore water depth of some 10 m) CARTER (1974) has suggested a sedimentation rate of 0.6 mm/y for the previous 7,000 y. This agrees with the estimate of 0.69 mm/y for the modern mud blanket (PANTIN, 1966).

LEWIS (1973) has also suggested that the deposition on the shelf over the last 8,000 y is some 4.5 km^3 per thousand years and in the last 5,000 y progradation has claimed an area of 120 km^2 with an average sediment depth of 2 m. Further, for the important supply of the coarser material from the Cape Kidnappers LEWIS (1973) estimates a headland erosion rate averaging some 0.15 km^2 per thousand years.

3.0 The Coastal Geology and the Gravel Barrier Foundation.

This part reviews literature for both the terrestrial and the nearshore coastal geology and by observations. The literature centers upon nearshore shallow penetrating seismic profiles and terrestrial and nearshore down hole information.

It should be noted that the nearshore had the only core samples, all others are bore hole samples. Here a core is a unitary cylindrical sample whilst a bore hole sample is material extruded from the ground as a slurry mix.

LEWIS (1973) suggests a eustatic generated wave beveled surface. The one of primary interest is the SL rise W1 surface. Presumably this surface can be traced across shore and inland. Since the surface is distinctive, it could serve as a useful marker time horizon, to find the thickness of the most recent sediments and to find out the characteristics of the barrier foundation. The W1 surface is taken as a basement upon which the contemporary barrier rests. This W1 surface would also be the surface upon which any remains of a previous barrier could be expected to be found assuming a barrier migrating with a eustatic SL rise, or fall. There is a need to establish the geographical extent and depths of the W1 as a basement time marker over which the modern barrier may be migrating. To establish this basement there are published seismic and down hole information. As the SL rose sediments became transgressive units across the W1 basement and these would correspond to an Early W1 (located far offshore and occurring at the time of the Otiraian culmination), and as SL increased further the SL shifted inland the Late W1 should occur inland from the present coast.

3.2 The Nearshore Seismic Profiles and Cores and Bore Holes.

Three sets of information are selected:-

1. A set of seismic profiles for the coastline from Clifton to Tangoio, (Figure 2).
2. Nearshore cores, and
3. Nearshore bore holes.

3.2.1 The Nearshore Seismic Profiles.

Figure 2 shows the locations for ten seismic profiles that extend at right angles across the shallow nearshore to the 10 m isobath between Clifton and Tangoio (CARTER and LEWIS, 1976). These subsurface profiles (Figure 3) were obtained with a Raytheon RTT-1000(A) Portable Survey System using a 7 kHz signal. These seismic profiles indicate two subsurface reflector profile types for the nearshore HB.

The reflector surface is likened to a basement since there is no clear penetration deeper than this lower boundary. These two types of reflector have geographical distributions, so that:-

1) Type one profiles have strong subsurface reflectors and occur south of the Tukituki inlet towards Clifton, Cape Kidnappers (Figure 3, seismic lines 1 to 4).

2) Type two profiles have weaker sub-surface reflectors and are found north of the Tukituki inlet, (Figure 3, seismic lines 5, 6, 7 and 10).

Type One Profiles.

These profiles show near sea bed truncation of the subsurface sedimentary units that are indicative of wave planation, and form the southern HB submarine platform. Towards Clifton, the strong subsurface reflectors depict a shore parallel syncline developed within the Pleistocene. This syncline has limbs which dip 3° offshore and 4° onshore, whilst the synclinal axis plunges to the west (CARTER and LEWIS, 1976). The syncline appears to have a truncated surface and is perhaps analogous to the truncation of the Cape Kidnappers Castlecliffian by a rising SL. The sediments directly above the truncation are "presumed" to be Holocene with a thickness of 2 m. These 2 m thick Holocene deposits support the rising SL. The submarine platform is extensive observed as bathymetric shallows and reefs on the nautical chart NZ56 (1989).

Type Two Profiles.

Towards the north the seismic profiles have Holocene sediments to the penetration limit at some 2 m to 5 m. This suggests that the basement (Pleistocene) is deeper and is likely down folded into the Hawkes Bay syncline (CARTER and LEWIS, 1976).

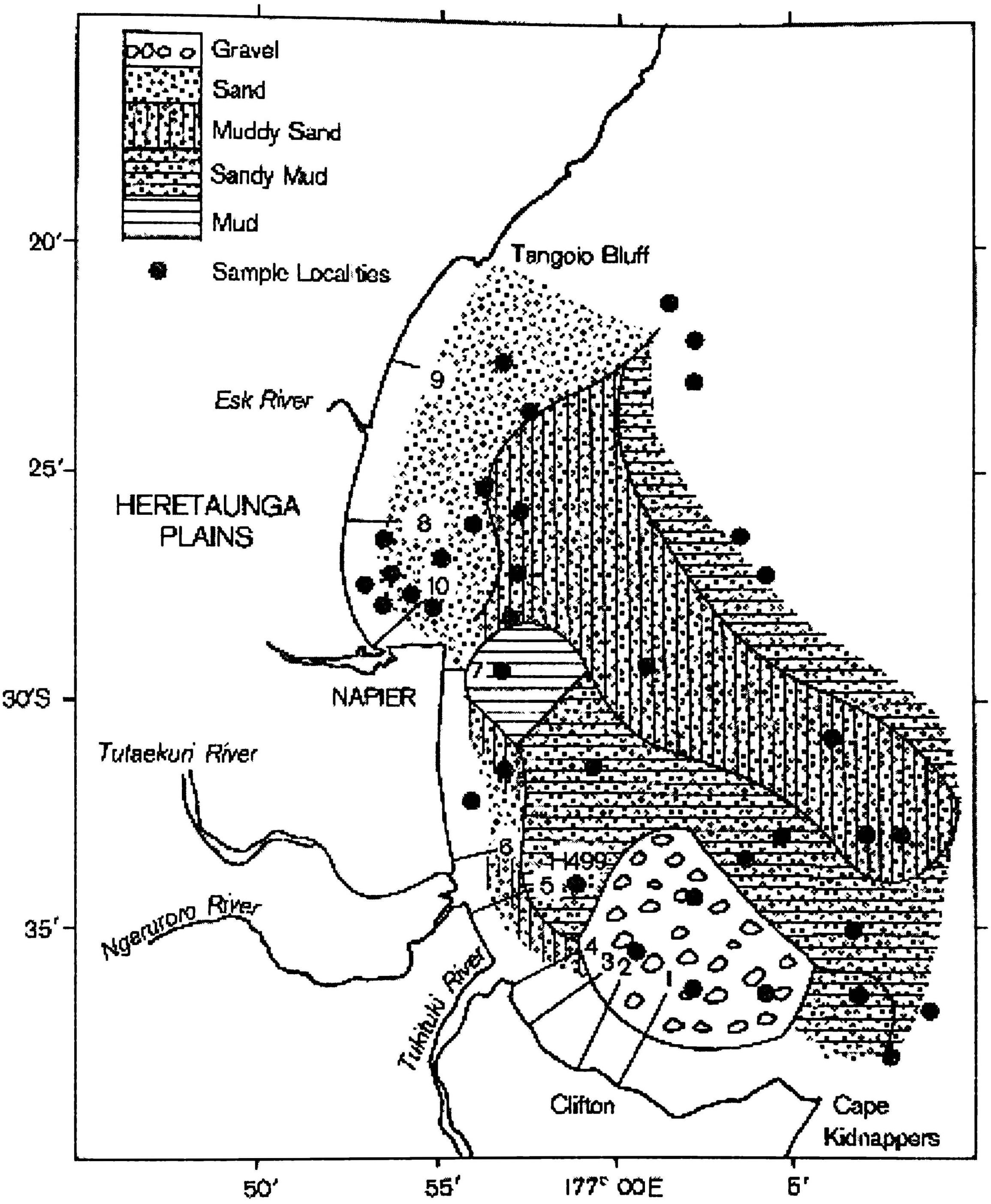


Figure 2. Location of seismic profiles, and nearshore surficial sediment textures. (CARTER and LEWIS, 1976).

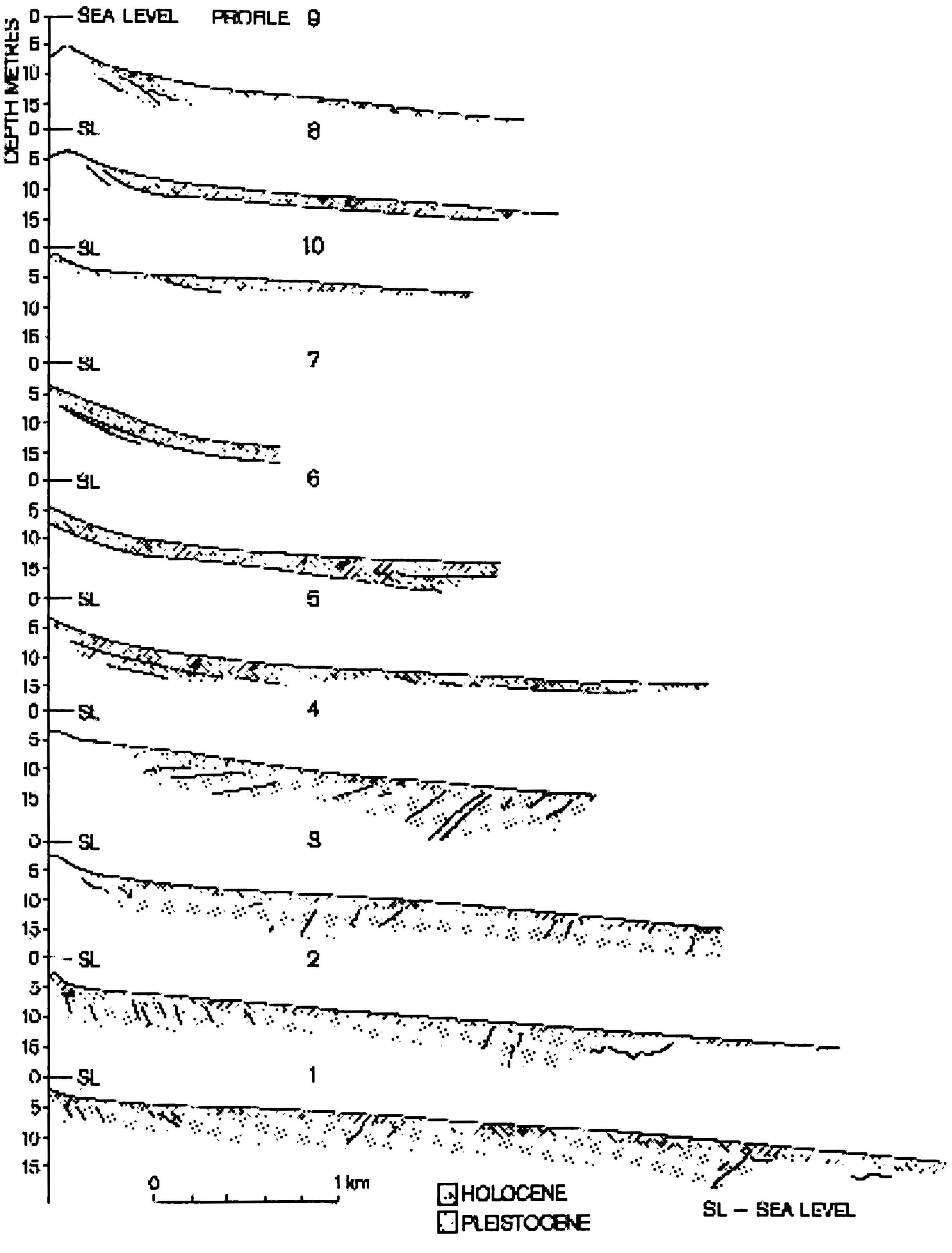


Figure 3. Inshore seismic profiles, Hawke Bay. Location of profiles see Figure 2. (CARTER and LEWIS, 1976).

3.3 The Nearshore Core and Bore Holes.

Two data sets are selected to indicate the nearshore stratigraphy and sediments.

1). Clive cores - a Holocene sedimentary column without a consolidated rock basement (Figure 3, seismic profile 6, Awatoto)

2). Scinde Island Reef bores - a sediment column with a consolidated basement.

The Clive Cores. (W21 500730 and 525745, approximately)

Off shore and between the Tukituki and Ngaruroro inlets CARTER (1974) reports a series of four piston cores taken along a transect corresponding to seismic line 5 (Figure 3) in water depths of some 12 m to 20 m which are approximately 3 km and 6 km off shore (Figure 1). These cores reveal that the surface and subsurface sediments are mostly muds with thin layers of sands usually containing pelecypod shells. CARTER (1974) observed that the muds overlay sands dated to the Flandrian (Aranui) transgression some 7,000 y BP and that the muds have accumulated since then. These data are possibly from core H 498 with basal muds at 7,000 y BP some 4.5 km offshore. In an adjacent core, H 499, (located on Figure 2) are sandy gravels with muds, occurring below the 7,000 y BP horizon. This suggests that the deeper sandy-gravels are older than 7,000 y BP. CARTER and LEWIS (1976) suggest that these sandy-gravels form the base of the Holocene at 10,000 y BP. The regional sea level could have been approaching a - 28 m still stand from a level at - 46 m some 11,000 y BP (CARTER, CARTER and JOHNSON, 1986).

These possible time horizons correspond to depths below the contemporary sea bed, for H 498, -2.7 m (7,000 y BP) and H499, -4.0 m (10,000 y BP). The approximate water depths (MSL) for these bore sites are (H498) -12 m and (H499) -13 m (NZ59, 1989).

Hence the time horizons relative to MSL, some 4.5 km offshore are:-

Core No	Water depth (m)	Time horizon depth (MSL m)	Date y BP
H498	-12	-14.7 m	7,000 y BP
H499	-13	-17 m	10,000 y BP.

The time horizon of interest is H498 at -14.7 m (MSL); 7,000 y BP.

Unfortunately the composition of the pebbles is not available, they could be greywacke pebbles from the early stages of cliff retreat along Cape Kidnappers, and/or Scinde Island limestones.

Scinde Island Reef Bores. (V21 473853 to 474851).

These exploratory bores were obtained for foundation piles prior to the extension of a wharf for an export log holding area for the Napier Port (WORKS CONSULTANCY SERVICE, 1993).

These bores represent a northern continuation of the Scinde Island geology offshore prior to the port construction and the pre-1931 earthquake shoreline uplift. The bores are approximately shore parallel some 500 m off the original shore in water depths ranging -2.5 m to -7 m (MSL) to the northeast off Scinde Island.

The cores indicate the shallow subsurface geology from a set of three drawings (not presented) as (1) logs of the nine bores, (2) one of these bores logged in more detail, and (3) a plan view of the sites for the nine bores.

The Nine Bores.

The bore information comprises the degree of cementation (weak cementation and uncemented) of the arenites and therefore divides these into the cemented marine silts at depth and the uncemented drape of sands and silts at the top of the bores. In some holes, the siltstones are intercalated with uncemented silts.

What is of interest here is the uneven thickness of the cemented siltstone surface below the uncemented sediment drape. The uneven thickness of the sediment drape ranges from some 2 m to 8 m, averaging some 2 m to 4 m. It is likely that the sediment drape has deposited upon the rocky reef only in relatively recent decades. At the same location as these bores, an early bathymetry chart indicates rocks at the sea bed and irregular water depths between 7.0 m to 7.6 m (PORT AHURIRI ROADSTEAD and HARBOUR 1854 to 1882).

Therefore, the bores pass through what was part of the reef platform off Scinde Island. Indeed, continuations of the reef off the port breakwater still exists as Town Reef to the east, and further off shore to the north Pania Reef (NZ 56, 1989). It is possible that the cemented platform siltstones represent a Late W1 surface (especially if weathered) of LEWIS (1973). The closest seismic profiles (CARTER and LEWIS, 1976) indicate Holocene sediment some 4 m thick off Marine Parade to the east.

3.3.1 Interpretation, Off Clive Cores and Scinde Island Bores.

Off Clive the nearshore cores show Holocene muds up to 4 m thick, whilst the seismic profiles depict an inshore sediment wedge some 4 m to 5 m thick. If, during the Holocene, the barrier migrated across the W1 surface with the eustatic SL rise then a course lag could be expected, but the gravels in the core H 499 cannot for certain be classified as lag deposits from a previous barrier site.

Off Scinde Island the bores and historical charts indicate an inshore platform with reefs, possibly a Late W1 surface. However, about Scinde Island the thickness of the Holocene sediments varies. To the south of Scinde Island off Marine Parade (Figures 2 and 3; seismic profile 7) the Holocene is some 4 m thick (CARTER and LEWIS, 1976). The reefs off Scinde Island were a dissected shore platform some 500 m wide (PORT AHURIRI ROADSTEAD and HARBOUR 1854 to 1882). This platform is composed of siltstones that are likely the (Early Pleistocene, Nukumaruan) Taradale mudstones (BEU and EDWARDS (1984). KINGMA (1962) describes these lithologies as “sands and silts with sporadic greywacke pebbles”. BEU and EDWARDS (1984) indicate that the Scinde Island coquina limestones are geographically restricted within the Taradale mudstone. Resting upon these consolidated basement rocks are sediments as a recent drape some 2 m to 8 m with no apparent Holocene.

There are no reports of gravels contained within any of these port area bores or in the unconsolidated sediment drape. This suggests that the contemporary gravels are restricted to the barrier fringing Scinde Island.

The off Clive cores suggest the contemporary barrier rests upon Holocene muds. About Scinde Island the modern barrier rests on a consolidated Nukumaruan basement, which may be consistent with the basement W1 surface.

4.0 The Onshore Bore Holes.

Selected near coast bores (those adjacent to the modern coast), are presented. Whilst there are many bores across the Heretaunga Plain aquifer these are mostly shallow and few are logged for the information necessary to determine palæo-gravel barriers or their proximity. Fortunately, the local drillers have good knowledge on the general subsurface lithologies and the most unusual sites, for example those that have abundant marine shell material. It is assumed that gravels associated with marine shell material are indicative of a MSG barrier environment.

4.1 The Near Coast Bore Holes.

These bores are adjacent to the modern barrier.

Four sets of information are reviewed. The first two bores are both in the Ngaruroro - Tutaekuri River confluence area, the third set is for Napier, and the fourth bore is in Te Awanga.

The Ngaruroro - Tutaekuri River confluence area has two sets of information, the Railway bridge shallow bores, and the Awatoto deep bore (scientifically logged).

Napier information is from bore holes in the Napier area reported by GIBB (1996).

Te Awanga information is from observation for a Burdens Vineyard bore.

The Railway Bridge Shallow Bore Holes. (V21 469753)

These three bores comprises a ground investigation for a railway bridge foundation and penetrate to some - 30 m (MSL), and are sited between the coast and the Awatoto deep bore (Figure 1).

The bore logs (NEW ZEALAND RAILWAYS, 1962) are some 250 m to 350 m inland, and are sub-parallel to the contemporary barrier along a length of some 230 m. All cores contain sedimentary silts, sands and clays and some reworked pumice. There are only two reports of gravel size sediments. Bore hole No 1 has pea metal with black and blue sand at - 27 m (MSL) and in bore hole No 3 "water worn gravel" with blue silty clay at - 5 m (MSL). Neither of the gravel deposits are said to contain marine shell material. The biological material (vegetation and shells) in all bore holes is associated with fine-grained alluvial sediments.

Only in the upper portions of the bore holes is the shell material said to be 'sea shells', below these depths the material is reported as 'shell'. The shell material occurs in layers of various thicknesses and at various depths that very likely pinch out between bore holes.

The Awatoto Deep Scientific Bore Hole. (V21 452744).

This bore hole log is for an investigation into the Heretaunga aquifer and is - 254 m deep (about MSL). It is the deepest and most accurately logged bore hole within the contemporary coastal environment (Figure 1). BROWN and GIBBS (1996) give an account of the strata and BEU a detailed palæontological account for the samples taken at 0.5 m intervals from sections of the deep bore hole.

It is useful to summarise the BROWN and GIBBS (1996) information, especially the gravels and the possible barrier fossil assemblages (Table 1).

Gravels are reported at the following depths (relative to MSL) and also included is a brief annotated description from the log. A possible proximal gravel barrier is marked **oo**

Also included are the yellow strata which characterise a terrestrial environment and have some bearing on the early W1 surface as discussed later from the inland bore holes (Section 4.5).

-35.5 m and -64.5 m	the gravels are isolated clasts in an otherwise mud-silt matrix with thin sands. The macrofossil assemblage is estuarine with a proximal sandy coast and rocky reefs.
-36 m to -37 m **oo**	"blue gravels with sporadic shell and wood fragments". Dated 6,922 y BP to 8,320 y BP; approximately 7,000 y BP

Unfortunately, there are no shell samples from between - 35.5 m and - 64.5 m.

-86.4 m to -90.8 m		brown gravels with yellow/brown silts. No date. Possibly 20,000 y BP
-92.5 m		marine shell fragments and egg shell fragments thought to be moa and trace fossils though to be root moulds. The Awatoto area was dry land, i.e., all fossil material is fragmentary.
-112.5 m		dated at 70,000 y BP, Table 1. At this horizon the gravel sizes are limestone from the north, from Scinde Island. Silts are yellow/brown.
-117.5 m	**oo**	this horizon is the first report of a gravel horizon with identified shell material (Table 1). This is for a blue/grey gravel with limestone/sand/shell/silt. The shell sample is described by BEU (pers. comm.,) as

"NZFR No. V21/f314 Sample depth 117.0 m

As for f304-9, f313, mostly (at least) reworked Nukumaruan fossils. Species reworked from Nukumaruan mudstone include:-

Austrofusus taitae
Murexsul espinosus
Amalda mucronata erica
Amalda opima

a pretty definite Nukumaruan fauna!

But again, the fresh-looking (but here incomplete) brightly coloured 2 specimens of *Zethalia zelandica* might well date the Holocene/last glacial deposit.

Z. zelandica lives very abundantly today in the surf zone (c.5 m of water) of open ocean beaches, so could well be contemporaneous with the gravels."

-187 m	A date of 200,000 y BP corresponds to an interglacial and MOI 7 (Marine Oxygen Isotope). A MOI 7 date corresponding to 210,000 y BP is given for South Wanganui BEU and EDWARDS (1984). An Amino Acid Racemisation (AAR) date for a *Anadara trapezia* from -220 m is consistent with an interglacial (the Karoro interglacial) at MOI stage 7. This is about equivalent to the Mid Haweran Series, Upper Pleistocene.
-199 m and -234 m	The taxa become more varied and plentiful between these depths with a more mixed estuarine and ocean beach assemblage. Nearly all samples are worn and representative of a death assemblage, and have transported in a turbid water.

	Possibly early Karoro interglacial?
-234 m to - 242.5 m	The taxa become much less varied and fewer. The gravel pebbles are Torlesse greywacke and Scinde Island limestone. Possibly Waimaunga glaciation, MOI stage 8?
-254 m	brown grey gravels with yellow sandy silts, c 250,000 y BP?

Napier Bore Holes. (localities not published)

GIBB (1996) suggests that the gravel barrier was in place "about 7,000 to 7,500 y BP" based on the radio carbon date of a mollusca, -11 m below MSL at Napier and at Hastings "indicates that the southern barrier was in place at this time cutting off a shallow embayment in the lower Heretaunga Plains to form an estuary" so that over the last 6,600 years the estuary has been buried by river sediments.

Burdens Vineyard. (W21 514666)

In 1992 a bore for a water supply in Te Awanga, (Figure 1), showed some 6 m of mixed sand and gravel resting unconformably upon a blue siltstone, at least 20 m thick, thought to be Late Castlecliffian siltstones similar to that visible on the modern Clifton beachface. This site is some 600 m inland from the modern barrier.

The site is a 50 m wide terrace some +8 m (MSL) resting against what is considered to be a fossil cliff with a crest height some +20 m (MSL). LEWIS (1971) suggests fossil cliff formation took place some 5,000 y BP, thus placing the terrace sediments (mixed sands and gravels) at about 5,000 y BP, or younger.

Grave	Depth m	Age y BP	SL m	Environ	Erosion Plane	MOI	Glacial/Interglacial
	-14.5	1180	1	River			
		6500	MSL	Tidal river			
▬	**B -36**	6922					
■	-39.5						
■	-40.5						
		10000	-28				
■	-64.5	14000					
■	-65.5	15000	-75				
		20000	-110	Glacial	W1	2	**Otira**
■	-102.5						
■	-103.5						
	-108	55000		Early	W2	3	
	-112	70000		Glacial			
▬	**B-117.5**		MSL	Moa egg shell and mangrove			
		80000				5a	
		120000		Interglacial			Kaihinu
■	-160.5						
■	-161.5						
			Bevelling of the Cape Kidnappers surface until near 120000				
		140000		Glacial	W3		**Waimea**
		210000		Interglacial			Karoro
■	-249.5	250000					
■	-250.5						
		320000					
		340000					**Kawhaka**

Table 1. The Awatoto deep bore hole, major gravels, depths, age, relationship to MSL, environment, erosion planes, Marine Oxygen Isotope, glacial/interglacial; after BROWN and GIBBS (1986); CARTER et al. (1986); LEWIS (1973); BELL and EDWARDS (1984) and NEWNHAM et al. (1999).

■ Gravel strata

▬ **B** Previous gravelly barrier

4.1.1 Interpretation of Near Coast Bore Holes.

Railway Bridge.

It is very likely that the environment of deposition is a tidal coastal swamp with abundant shell material in varying proportions throughout the fine sediments.

The - 5 m (MSL) gravel has a mud matrix, perhaps similar to those which can be observed at the base of the modern Maraetotora and Tukituki river inlets following a sediment scouring event. These muddy matrix very well sorted large gravel sediments are indicative of a fluvial inlet.

The -27 m (MSL) gravels contain black sands that could be similar to those observed to occur as lag sheets following high seas on the modern beachface. It is possible that these pea metal gravels with black sands represent a near beach environment, possibly within a tidal channel.

Both gravel strata are thought to represent a lag deposit in a tidal channel, the missing shell material is problematic as even fragments could be expected in a tidal reach environment.

The stratigraphic separation of the gravels, firstly with non-lateral continuity suggests very localised, thin pocket (sheet) deposition, and secondly the vertical separation suggests very intermittent supply. Black sand and gravel mixes are found on the contemporary beach profiles especially towards the Cape Kidnappers (where they are associated with tephra) at the high water zone. Black sands tend to accumulate where the water flow is oscillatory and sediment sorting is by density separation with the less dense fines selectively removed by winnowing. The well-sorted nature of the gravels also suggests oscillatory flow, as near a tidal inlet.

The paucity of gravels in the stratigraphic column strongly suggest that the supply of gravels was small and that the gravels if they did occur were concentrated in a particular environment, i.e., the barrier ridges, as they are today.

Awatoto.

The top -64 m (MSL) represents a predominantly muddy estuarine environment. Within these muds there was a possible 'pulse' of gravels 1.0 m thick at -39 m (MSL). This gravel is some 7,000 y BP. These gravels are blue, indicating an estuarine depositional environment. This layer also contains shell and wood, however, we do not know the clast sizes or if they are graded. Grading and internal bed structures can indicate the type of gravel depositional environment, for example, mass flow deposition is characterised by a "lack of sorting and internal stratification" (TODD, 1989). However, this 1.0 m thick gravel layer may be a river bed traction load deposit.

Below these horizons of interest longer time scale trends may exist. For example do sediment stratigraphic sequences show characteristics, which repeated and could represent similar environments of deposition, for example, gravels tend to be associated with the onset of and postglacial environments.

At -92 m the indications are that Awatoto was dry land and at - 117 m the first identifiable fossil assemblage equatable to a gravel barrier. It is possible that these gravels represent a gravel barrier beach system in this locality. The date of these gravels is some 75,000 y BP, during the last interglacial (Kaihinu) (LEWIS, 1973). The indicators of terrestrial depositional environments are grey gravels with yellow/brown fines.

Below these horizons, the sediment strata are grey or blue gravel, where the grey clays are considered to be fluvial - and the blue clays are indicative of estuarine depositional environments. The clay strata fossil assemblages indicate a near tidal channel to an estuary with a proximal open coastal sandy beach - nearshore environment. Fragments of wood occur through the clay strata. There are no gravel layers with shell indicative of a gravel barrier depositional environment.

In general, the gravels are described as (1) greywacke originating from the Ruahini Ranges, or (2) derived from Scinde Island limestones. Scinde Island gravels occur through the lower bore column from -64.5 m to -195 m, with a time range of 14,000 y BP to approximately 200,000 y BP. This suggests shifts of supply and/or the availability of a supply of gravels to the Awatoto area, geographically located mid way between Cape Kidnappers, and Scinde Island.

4.2 Synopsis of the Near Shore Bore Holes, Indicators of the Hawke Bay Quaternary Terrestrial - Coastal Environments.

This section is divided into a (1) marine part, and (2) terrestrial part.

Marine Part.

1). LEWIS (1973) suggests the two contemporary erosion surfaces W1 and W2 in the seismic reflectors beneath the HB seabed correspond to a falling (W2 early Otira) and a rising (W1 late Otira) eustatic SL with the characteristic wave planation of the surfaces. These surfaces are also tilting with the inner shelf rising as the East Coast subducts (LEWIS, 1973). The nearshore expression of W1 is thought to be at the base of core H 499 some 4.5 km off Clive in some 13 m of water, consisting of sands and gravels deposited some 10,000 y BP (LEWIS, 1973; CARTER and LEWIS, 1976).

2). Also off Clive in some 12 m of water is a time horizon of 7,000 y BP at -14.7 m (MSL) for core H 498 (CARTER, 1974) and this is used because it has a stratigraphic date similar to onshore Holocene strata composed mostly of muds with thin sands.

3). Off Scinde Island there was a beveled platform with inshore reefs in some 7 m of water (PORT AHURIRI ROADSTEAD and HARBOUR 1854 to 1882). It is possible that this platform is synonymous with the W1 basement (time horizon). In recent time unconsolidated, mostly silty, sediments some 2 m to 4 m thick (WORKS CONSULTANCY SERVICE, 1993) have draped across the reef within the port breakwater.

4). Off Clive the length of seismic survey line falls short of reaching the core H498 site, but inshore between water depths of 10 m to 4 m the sediments along the trace are some 4 m to 5 m thick.

5). The seismic trace off Te Awanga across a wave planed platform with reefs (NZ 56, 1989) indicates folded and beveled consolidated rocks (Pleistocene) with a thin 2 m to 3 m thick Holocene cover.

Terrestrial Part.

1). In the Awatoto area the sediments are mostly muds to some -39 m (MSL).

2). Thin gravels occur in the upper Rail Bridge muds (at -5 m (MSL), and at -27 m (MSL)) and may be channel deposits proximal to a coast.

3). A strata of gravel 1.0 m thick occurs in the Awatoto Deep bore at -39 m (MSL). A date on this gravel is reported as 6,922 to 8,320 y BP (approximately 7,000 y BP). This 1.0 m gravel could be an onshore expression of the W1 surface off Clive as a near coast gravel, possibly estuarine, or overwash gravels. It is of interest that the Awatoto bore also indicates two possible proximal gravel barriers, firstly at some 7,000 y BP (at -39 m (MSL)); and secondly at 75,000 y BP (at - 117 m (MSL)) with the latter towards the close of the Kaihinu interglacial between MOI 5a and 3. Below these depths the Awatoto bore has a succession of muds and gravel strata, with likely correlation to major glacial and interglacial periods of the Castlecliffian.

4). GIBB (1996) suggests for Napier a time horizon of some 7,000 y BP at -11 m (MSL). It is suggested that this horizon is likely from marine shell material contained in muds. If this is so then the modern barrier may also rest on mud adjacent to Scinde Island, indeed GIBB (1996) suggests that bores show the barrier in Napier to be 25 m to 27 m thick. However, we do not know if this pile of gravelly sediment represents continuous sedimentation, or if the column contains different time depositional strata.

5). In Te Awanga the Burden's bore has 6 m of unconsolidated mixed sands and gravels overlaying a Late Pleistocene siltstone similar to that found at Clifton beachface. It is estimated this unconformable surface is at +2 m (MSL). LEWIS (1971) suggests that some 5,000 y BP the culmination of the eustatic SL rise formed fossil cliffs inland from Napier, and perhaps those at Te Awanga, hence the unconformity beneath Te Awanga may correspond to the W1 surface planation between some 7,000 y BP to some 5,000 y BP.

4.3 Synopsis - Near Shore Cores, Bores and Seismic Profiles.

There are five summary aspects from the previous summations.

1). The varying depths of the W1 time horizon expressed by seismic reflectors and cores from inshore waters and inland,

2). The possible geological configuration of this time horizon and sediment thickness.

3). The sedimentary composition of the contemporary barrier foundation (W1 time horizon).

4). Barrier genesis.

5). Gravel supplies and supply.

Depths of the HB W1 Time Horizon Across the Contemporary Barrier.

The W1 (approximate 7,000 y BP) basement has expression at various vertical distances about MSL.

OFF SHORE	ON SHORE
Off Clive -14.7 m (MSL)	onshore at Awatoto -39 m (MSL),
Napier -11 m (MSL)	platform - reef north of Scinde Island some -7 m (MSL).
Te Awanga +2 m (MSL)	possible wave beveled Late Pleistocene.

Geological Configuration of the W1 Time Horizon.

This can be illustrated by four transect lines with a similar W1 (7,000 y BP) time horizon, with three cross-shore radiating from a common point off Clive (core hole H 498) and the forth transect alongshore from Scinde Island to Te Awanga.

The three cross-shore transects are, from off Clive H 498: -

1). off Clive to Napier, the W1 surface has a slight vertical increase from -14.7 m to -11 m (MSL).

2). Awatoto, the W1 surface slopes landwards to the west from -14.7 m to -39 m (MSL).

3). Te Awanga, the W1 surface increases in vertical height from -14.7 m to +2 m (MSL).

The longshore transect is: -

4). In the longshore direction the W1 surface slopes towards Awatoto from both Napier and Te Awanga. From Napier the slope is from -11 m to -39 m (MSL) and from Te Awanga the slope is from +2 m to -39 m (MSL).

The LEWIS (1973) suggestion of a vertical tilting W1 inner shelf is supported by the cross-shore transects, however, along the length of the coast with expressions of uplifting headlands and subsidence between these headlands. Napier has a slight uplift, and Te Awanga a marked uplift, but at Awatoto, the trend is strongly reversed with a marked subsidence.

Accordingly the Holocene sediment thickness above the 7,000 y BP time horizon, varies, for example:-

1). Inshore seismic profiles suggest varying thicknesses of Holocene sediments ranging from a minimum (2 m to 3 m) off Te Awanga, to a maximum off Clive (4 m to 5 m).

2). Onshore at Awatoto the Holocene sediment column represented by 7,000 y BP time horizon is 39 m thick, whereas at Te Awanga the Holocene column is 6 m thick resting upon a Late Castlecliffian bedrock.

Sediment Composition of the Barrier Foundation (Holocene Sediment Pile).

The sedimentary composition of the contemporary barrier foundation varies along shore between Scinde Island, Awatoto, and Te Awanga (Clifton).

At Scinde Island, the barrier rests upon two lithologies.

1). Firstly, at Scinde Island the barrier rests upon Nukumaruan, Taradale siltstone and likely coquina limestones.

2). Secondly, it is likely that the barrier rests upon muds (that supplied mollusca for dating) especially away from Scinde Island, possibly at Westshore. Recent research investigating tsunami deposits in Ahuriri Lagoon indicate Holocene muds (CARTER, et al., 2000).

At Awatoto, the modern barrier rests upon unconsolidated Holocene mud.

At Te Awanga to Clifton, the barrier also rests upon two lithologies.

1). Firstly Late Pleistocene siltstones at Clifton (exposed periodically in the beachface).

2). Secondly in Te Awanga (Burdens Vineyard) possible Late Pleistocene.

This leads to a 'foundation' model for the modern barrier. At the headlands, the barrier rests upon relatively hard cemented rock, whereas between these headlands, at Clive - Awatoto the barrier rests on deep mud. Therefore, the nature of the barrier foundation varies between 'grounded' on hard rock, to 'suspended' on muds.

The Hawke Bay Barrier Genesis.

These are formulations on the Holocene barrier genesis.

1). The headlands have wave planed platforms with reefs fronting cliffs. The erosion and planation of the headland platforms would have initiated supply from the available gravel sized material directly to the shore and this is especially so for the much larger headland of Cape Kidnappers that contains conglomerates composed of hard greywacke clasts.

2). Supply of gravel may have reduced as continuous planation increased the width of the platform with subsequent reduction of incident wave energy to the headland.

3). The early barrier probably began at the headlands as a fringing, stranded barrier. For example, the Te Awanga inland perched barrier resting upon Late Pleistocene siltstone and trapped against the low 20 m cliff.

4). As supply continued the barrier may have undergone extension alongshore, for example towards Haumoana, across a wave planed Plio - Pleistocene surface.

At Awatoto, the Rail Bridge near surface gravels are thin and laterally none continuous. Within the Awatoto bore the stratigraphy shows the first gravel dominated strata are approximately 7,000 y BP at -39m (MSL), and only 1.0 m thick and appear to have a marine component (shell material). Generally, the Awatoto bore strata are dominated by thick muds. These Awatoto thick muds indicate an insignificant supply of gravels from inland and are considered insufficient to maintain a barrier directly from the inland Ruahini Ranges so that the 1.0 m thick gravels at -39 m are perhaps via longshore transport from the Cape Kidnappers.

The Awatoto - Clive length of coast is characterised by muds both to seaward and landward of the modern barrier. The evidence suggests that the early genesis of this length of coast was a tidal inlet connecting the swamp accumulating muds to landward, possibly with flood tidal deltaic sequences of thin gravel. These would be more consistent with longshore extension of a barrier system with possible overwash.

For Scinde Island an early barrier genesis may have been similar to the Cape with a fringing barrier trapped against the cliff and supplied by local material. However, this material is envisaged as predominantly coquina limestones and siltstones. However, no evidence to support this suggestion has been reported from Napier bores. Therefore, greywacke gravels from Cape Kidnappers may have by - passed the tidal inlet(s) at Awatoto to become stranded against the Scinde Island cliffs.

Gravel source and supply.

The bore log of BROWN and GIBBS (1996) appears to suggest that the composition of the gravels found at Awatoto changed from a combined greywacke and (Scinde Island) limestone to a gravel of only greywacke. The proportion of greywacke and limestones is not given. This change of gravel lithology could be due to a variety of causes. It could be construed that limestones are more common in glacials, with a SL further to the east and the greywacke confined to river channels. It is also considered and perhaps more likely given the tectonic nature of the Hawkes Bay region that the tectonic warping could alter the direction of gravel transport from a fixed source (the inland Ruahini Ranges). This may be apparent in the Awatoto bore where Scinde Island limestone gravels appear to decrease above - 64.5 m (MSL) or some 14,000 y BP.

5.0 Implications from the Seismic and Core - Bore Hole Information.

BROWN and GIBBS, (1996) and GIBB (1996) surmise that the modern greywacke gravel barrier south of Napier was in place 6,500 y BP but there is no direct evidence to suggest that this is so and where, especially on a line through off Clive - Awatoto to Hastings.

It is vegetation and shell material that has been dated for the various publications (BROWN and GIBBS, 1996; GIBB, 1996; OTA, et al., 1988). The oldest date within these fine sediments is 10,247 y BP (BROWN and GIBBS, 1996). Even the dating of material is not without possible errors (for example see JENNINGS, CARTER, and ORFORD, 1995). Vegetation as a dating material tends to skew the age to a younger result, especially peat, whereas shell material tends to skew the date to an older date. This skew is a product of the environment the material is derived from since plant material tends to fresh water on intertidal flats and most likely accumulating sediment. Shell material is seldom found in situ and mostly lives in a sub-tidal environment and appears to occur as death assemblage material, from an erosive environment, and may well have undergone transportation. Between these limits a SL is construed. For example OTA, et al. (1988) data includes shell material which consistently gives greater subsidence rates than a peat, which gives a smaller subsidence rate for Hastings.

From a MSL datum, the top muds have various thicknesses, however muds are not present in all bores, for example the Te Awanga Burdens bore. In fact, the muds can be regarded as absent at the headlands of Scinde Island (ignoring the possible drape of mud within the port area) and Te Awanga - Cape Kidnappers. It is across these muds between the headlands that the contemporary barrier straddles as a suspended barrier (Figure 4).

Reviewing the Holocene W1 horizon and subsidence rates, it appears that mud thickness increases from offshore Clive to Awatoto, in terms of the late W1 time horizon, and also in terms of absolute thickness of muds, from Awatoto to Mangateretere (near Hastings, north).

At Clive some 4.5 km offshore the base of a core, has a suggested time horizon of 7,000 y BP and is at some -14.7 m (MSL) (CARTER, 1974). At the coast for Awatoto, a time horizon of some 7,000 y BP is given for gravels at -39 m (MSL) (BROWN and GIBBS, 1996). For Napier GIBB (1996) places a time horizon of 7,000 y BP at -11 m (MSL). For Scinde Island a wave planed platform surface may have been near - 7 m (MSL) (PORT AHURURIRI ROADSTEAD and HARBOUR, 1854 to 1882).

Inland at Hastings an average time horizon of 6,635 y BP is presented for the average depth of -24.8 m (MSL) by data from OTA, et al. (1988). This suggests that the Awatoto - Clive coast is subsiding and at a rate greater than at any of the other measured localities.

GIBB (1996) suggests that the Hastings area has subsided -11 m, with an average rate of -1.7 m / 1,000 y. BROWN and GIBBS (1996) also suggest that the inland Hastings area is subsiding but refer to compaction. OTA, et al., (1988) suggest rates of between -1.7 m/1,000 y and -4.4 m/1,000 y for Hastings.

The subsidence rate at Awatoto can be calculated as approximately -5.4 m/1,000 y. This may have some bearing on why the contemporary single crest barrier is located along an axis Awatoto - Clive - Haumoana. If Awatoto is subsiding at such a great rate and the area is forming a trough, or sink, then the sediments will accumulate by gravitating towards the area. However, this may be offset by the apparent deep trough between Awatoto - Mangateretere and possibly greater subsidence rate for the Mangateretere area.

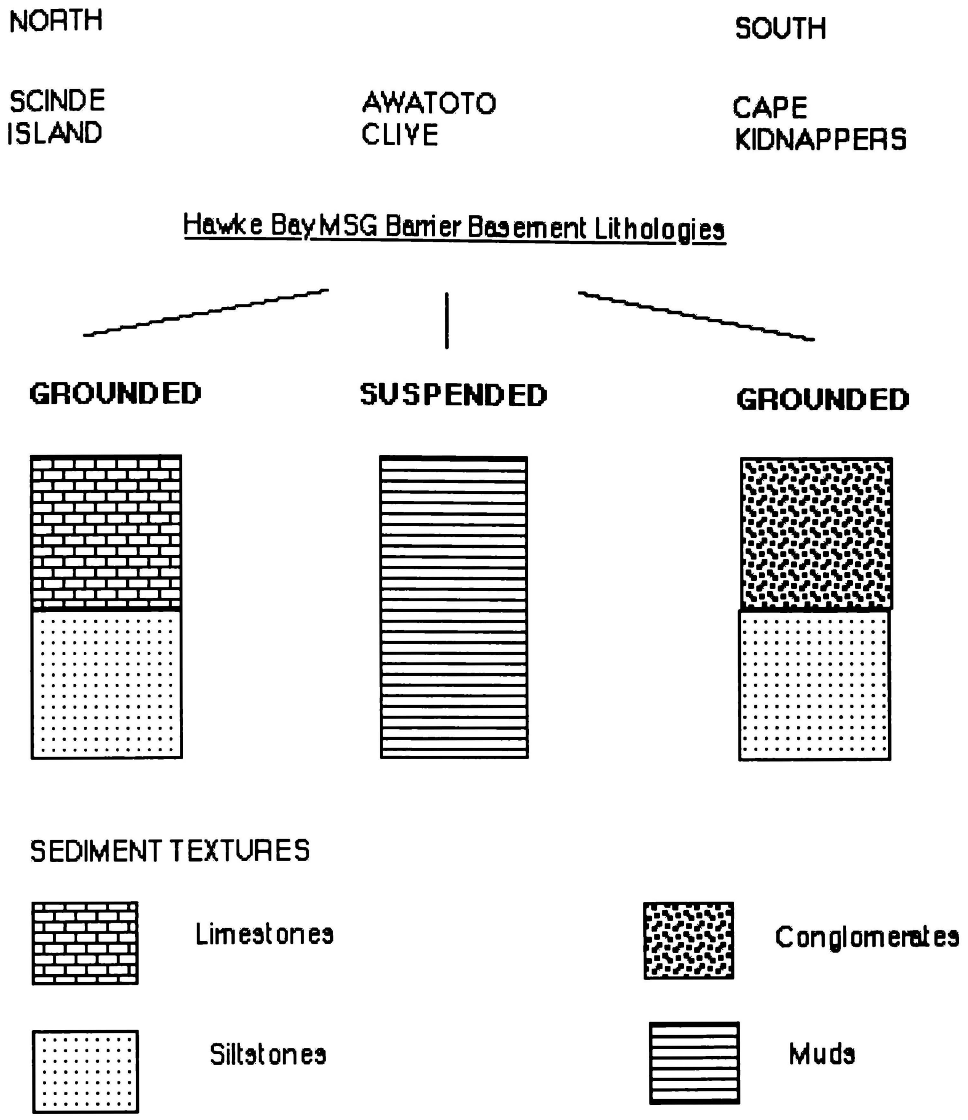


Figure 4. Southern Hawke Bay mixed sand and gravel barrier basement lithologies at Cape Kidnappers (Te Awanga) - Awatoto/Clive - Scinde Island (Marine Parade).

It is possible to support the Awatoto trough hypothesis. Since historical records began, the Tukituki and Ngaruroro river inlets have been near Clive (Awatoto). Indeed, it appears that the Tukituki inlet was actively migrating towards Awatoto as an abandoned inlet is located towards Cape Kidnappers in Haumoana (V21 490700). There is also evidence to suggest that the Cape Kidnappers is uplifting from a process of tectonic warping. Indeed CARTER and LEWIS (1976) indicate the Cape is on an active anticlinal axis. This would mean that the Tukituki inlet is migrating down dip and towards Awatoto. The seismic profiles (CARTER and LEWIS, 1976) Awatoto - Clive - Haumoana also indicate a thicker Holocene cover when compared to the adjacent profiles, to either at Clifton, or Westshore. Also there are no reported shallow gravels in bore holes across the Heretaunga plain, suggesting the contemporary MSG barrier has not migrated across the area, and that if anything it is transgressive or stationary about its present position. The deep muds also suggest with the absence of thick gravel strata within these top muds, then for some 6,500 y the Ngaruroro and the Tutaekuri have not supplied gravels to the coast.

6.0 Conclusions.

Some aspects of the initial three questions can be surmised.

1). First question - what does the modern barrier rest upon?

The barrier is considered a response to various forcing agents, with most response likely from eustatic SL rise. Therefore, a surface representing the Late Holocene eustatic SL across Hawke Bay is the most plausible time horizon (a 1.0 m thick gravel at -39 m dated at approximately 7,000 y BP) that may be equated to the LEWIS (1973) W1 seismic reflector surface across the continental shelf of Hawke Bay. At the continental shelf edge, the Holocene time horizon W1 is at some 20,000 y BP, and inland at 5,000 y BP (LEWIS, 1973). This shelf is also vertically rising in response to a tectonically active continental shelf laying across a subducting margin.

At the headlands the W1 surface is thought to be a Nukumaruan wave beveled surface below the contemporary barrier at Scinde Island, but at Te Awanga (Cape Kidnappers) the W1 is possibly +2 m (MSL) and some 600 m inland of the contemporary barrier and is a wave beveled Castlecliffian surface.

Muds are thick at the top of all the core and bore holes, except the headlands where they are not present. Muds have dominated the sedimentation for the previous 7,000 y BP across the Heretaunga Plains and to the coast at Clive and continues offshore to at least some 4.5 km offshore. Indeed the inshore seismic profiles show Holocene muds some 4 m to 5 m thick off the Awatoto - Clive river inlets, but they thin over rocky headland platforms. Muds are at their thickest at the coastal Awatoto, -64 m (MSL) - Mangateretere, - 60 m (MSL) suggesting a trough with an axis parallel to the Hawkes Bay syncline - Cape Kidnappers anticline axes of CARTER and LEWIS (1976).

This means the modern contemporary barrier rests on muds at Awatoto - Clive and is therefore a suspended barrier with a potentially soft 'rock' foundation. At the headlands, the modern barrier rests upon cemented siltstones/limestones at Scinde Island, and siltstones/conglomerates/tephras at Cape Kidnappers, and is therefore a grounded barrier with a hard rock foundation, (Figure 4).

OTA, et al. (1988) and GIBB (1996) consider the Hastings land surface as subsiding between some -1.7 m/1000 y to -4.4 m/1000 y, depending upon the dating sample (shell or plant material). At Awatoto a subsidence of - 5.4 m/1000 y is estimated for a 1.0 m thick gravel at -39 m (MSL) dated at some 7,000 y BP. This Awatoto subsidence is of a large rate. Alternatively, perhaps it is compaction. Te Awanga has uplifted with what is considered perched gravels on a wave planed surface at some +2 m (MSL) at Burdens Vineyard.

2). Is there any record of a previous mixed gravel - sand barrier?

Across the eustatic W1 surface there appears to be no suggestion of a previous barrier. The only possible is to seaward in core H499 at -16 m (MSL), some 6 km off shore where CARTER (1974) reports gravels with sands. These could be a lag deposit from a transgressive barrier, however these gravels are an isolate occurrence with no other gravels reported. The gravels also appear to be spatially restricted, where-as a transgressive barrier could be expected to leave extensive gravels in some form of lag veneer as suggested by HARTSTEIN and DICKINSON (2000) for Cable Bay, South Island.

Only at depth are there two possible previous barriers at Awatoto. The first is at -39 m (MSL) and the second at -117 m (MSL). The -39 m (MSL) barrier is tenuous since the gravels are blue and may represent fluvial - estuarine deposition since they contain black sands, an observed modern beach lag sediment.

The depth of -117 m corresponds to the Kaihinu interglacial at 75,000 y BP. The climate was warmer and it is perhaps possible that the south flowing, warm, East Cape current had a greater impact and influence on 'Hawke Bay' than present. Fossil *Mangrove sp* have been identified in the Awatoto bore hole at this depth (BROWN and GIBBS, 1996).

It is difficult to locate previous barriers in HB, where they could be expected to exist given gravels supplied by fluvial processes, and material available from the Cape Kidnappers and Scinde Island headlands. However, barriers also depend upon SL. In the post glacial Aranui SL has increased with oscillations, and still stands. With an adequate supply of material barriers could be expected to form during still stands.

3). Question three involves formulations of the Hawke Bay barrier genesis.

The geological evidence for the genesis of the HB barrier suggests headland supply since coastal and inland bores have thick strata composed of estuarine, blue muds and no gravel strata of any sufficient thickness to suggest a fluvial supply to a coast in the last 7,000 y BP.

The evidence for barrier evolution suggests longshore supply from headlands, mostly greywacke from Cape Kidnappers. HB greywacke gravels can be shown to be harder than their South Island counterpart (HEMMINGSEN, 2000). This suggests fewer greywacke gravels are required in HB to build and maintain a barrier geomorphology. This, combined with the Awatoto sink (trough), suggests the modern barrier is confined to a narrow corridor. The barrier is also extending down dip from the Cape Kidnappers anticline towards the HB syncline, to the north. It is also extending up an incline formed in the 1931 earthquake, when Scinde Island area up lifted some 1.8 m and the Tukituki subsided some -0.7 m. Interestingly enough Awatoto acted as a hinge about which the land surface tilted in the alongshore directions.

The Cape Kidnappers is the likely origin of supply gravels. This is high lighted by the perched gravels in Burdens Vineyard, Te Awanga, and these are considered a fossil beach deposit.

Scinde Island headland is another supply of material with limestone clasts found in the Awatoto bore between -64.5 m (MSL) and -195 m (MSL), and associated with the Otira glacial and previous Kaihinu interglacial, 14,000 y BP to 200, 000 y BP. Even until relatively recently (prior to beach stripping for port and other constructions) the Scinde Island foreshore contained abundant limestone gravels and these could be observed towards Awatoto along Marine Parade in historical photographs. The decline of limestone gravels in the Awatoto bore hole above 14,000 y BP suggests a change in the availability, and supply, or transport path(s).

Paraglacial barrier development is considered dependent on the antecedent conditions of geology and physiography (FORBES and TAYLOR, 1987) and the HB barrier is no exception. The contemporary barrier has close association to sub-aerial and sub-surface lithologies. Surficially the barrier extends between the two relatively hard rock headlands of Cape Kidnappers and Scinde Island. Both of these headlands have characteristic extensive wave planed platforms with reefs. Between these headlands, the barrier straddles thick (-64 m (MSL)) subsurface muds. Hence, the barrier is a fringing, grounded barrier at the headlands and between these is a suspended barrier on thick muds. The subsurface lithologies have also undergone tectonic deformation with a west plunging Castlecliffian syncline off Clifton - Te Awanga.

Appendix 2

Sea Level and the Genesis and Evolution of the Hawke Bay Barrier

SEA LEVEL AND THE GENESIS AND EVOLUTION OF THE HAWKE BAY BARRIER.

1.0. Introduction.

Contemporary barrier genesis can be related to the supply of sediments, the wave climate and the relative sea level (FORBES and TAYLOR, 1987; CARTER, et al., 1989). In this section the Hawke Bay (HB) Holocene relative sea level (SL) information is reviewed. It is considered possible that the HB SL was not a smooth eustatic increase but may have oscillated with consequences for the barrier genesis and evolution.

The HB is considered to have two identifiable relative SL components. The first is the relatively steady regional eustatic SL alteration and the second are the abrupt co seismic SL alterations. In this section the literature for the regional eustatic SL is reviewed. The co-seismic SL events are discussed in the section outlining the geology of the HB, Chapter 2.

The regional SL has two sources of information, with the first related to the published literature, mostly for the east coast of the South Island, and the second is for the HB SL from unpublished information which includes a report and bore hole logs.

A third SL aspect is also explored utilising observations made in shallow excavations within the coastal environment. One of the most likely sources of SL error for HB is the ongoing tectonic warping, for example the growing anticline at Cape Kidnappers (CARTER and LEWIS, 1976).

2.0 The Regional Eustatic Sea Level.

A reviewed of the recent literature indicates the regional SL may have increased with a series of still stands, but there are also indications of possible SL retreats taking place. The SL measures are relative to modern mean sea level (MSL) taken from the Port of Napier tidal station.

The Austral-New Zealand Eustatic Sea Level.

It is most likely that the HB contemporary barrier genesis dates to the postglacial eustatic marine transgression when no doubt the Cape Kidnappers Pleistocene gravels would have begun to erode and supply material directly into the coastal environment.

Since the culmination of the Otiran (most recent) glacial there have been several still stands when the SL remained virtually static for a longer period of time. Following on from the maximum low still stand at -113 m CARTER, CARTER and JOHNSON (1986) place eight still stands at the following times and depths below the present SL for the east coast of the South Island.

y BP	Shoreline at (m)
18, 000	- 113
17, 000	- 88
15, 000	- 75
12, 000	- 56
11, 000	- 46
9, 500	- 28
9, 000	- 24
7, 500	- 9
6, 500	0

CARTER, CARTER and JOHNSON (1986) demonstrate a greater than average SL rise between 12,000 and 9,500 y BP for the Australian Queensland coast when coral growth could not keep pace with the rate of increasing SL. At this time the SL rapidly shifted from - 56 m to - 28 m and given that 500 years later it was at - 24 m then if the HB coastline is contemporaneous to the Queensland coast then it to would have begun to experience considerable erosion. This erosion is supported by LEWIS (1973) who suggests that the 2 km wide beveled submarine platform around Cape Kidnappers may have been formed some 10,000 y BP when the SL was at - 50 m and rising. Relative sea level rise and drop have also occurred at Cape Kidnappers. KINGMA (1971) writes of Holocene deposits at Cape Kidnappers as "Remnants of raised beaches of not more than 25 feet (8.25 m) elevation are to be found along the coast only between Clifton and Cape Kidnappers".

The Regional Sea Level Oscillation.

It is also possible that the regional SL has fallen to its present level following a still stand. For the east coast of the North Island, to both the north and south of HB, OTA, et al. (1988) show a relative SL increase culminating some 5,500 to 6,300 y BP, followed by a reduction of SL height. This may not be the only instance of such a reduction of relative SL height, since BROWN and GIBBS (1996) also indicate a reduction of SL since about 1,200 y BP for the Hawke Bay.

These oscillations could have considerable consequences for the HB barrier, for example, similar mixed sediment barrier coasts may assume different geomorphologies depending on the SL increase (CARTER, et al., 1989), where these examples are from either side of the North Atlantic, but it is also possible that a barrier may pass through successions of SL oscillations.

3.0 The Hawke Bay Eustatic Sea Level.

There are two main sources of information. Firstly from published information, for example OTA, et al. (1988) and secondly from an unpublished report and bore hole logs that indicate the extent of inundation. The unpublished report of BROWN and GIBBS (1996) forms a basis for a local HB SL curve.

The Hawke Bay Eustatic Sea Level Curve.

BROWN and GIBBS (1996) introduce a local variation on the 'New Zealand Holocene eustatic SL curve' of GIBB (1986), Figure 1.

BROWN and GIBBS (1996) suggest that the modern interglacial (Aranui - interglacial) SL reached the Heretaunga Plain, upon which the city of Hastings is built, at about the present shore some 9,000 y BP; when the SL was at -25 m. Over the next 3,000 y, the SL continued to rise with the subsequent inundation of the Heretaunga Plain. A coastline established some 12 km inland from the present coast and to the west of Hastings. This is coincident with the OTA, et al. (1988) regional maximum some 6,300 y BP, but with the SL at some +10 m.

The BROWN and GIBBS (1996) data supports a regional SL rise (OTA, et al., 1988) but BROWN and GIBBS data also places a more recent higher SL at 1,200 y BP at +5.0 m.

A higher SL would have meant that much of the coastal geomorphology could have altered, for example the barrier may have eroded, or overstepped (buried), or smeared (transposed spatially) inland leaving a residual cobble pavement, however these characteristics have not been reported off Awatoto or indeed onshore.

OTA, et al. (1988) suggest that because of the subsiding inner HB and continuing sedimentation "the eustatic culmination of sea level cannot be recognised in the stratigraphic record". This suggests that for HB the SL alteration is a continuous process.

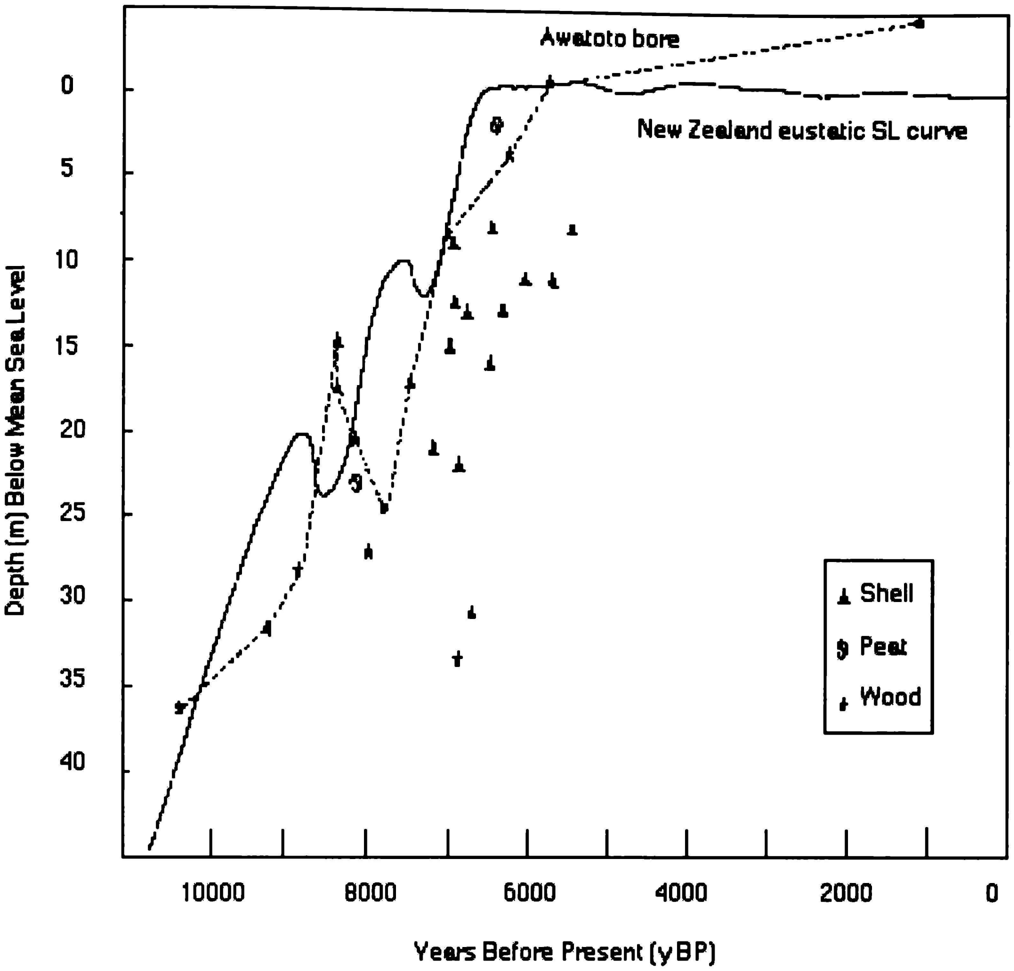


Figure 1. The Hawke Bay Awatoto (Heretaunga) eustatic sea-levels by BROWN and GIBBS (1996). Solid line (GIBB, 1986); dashed line (BROWN and GIBBS, 1996).

Indicators for the Landward Extent of Hawke Bay Sea Level Inundation(s).

Two main indicators are present across the Heretaunga Plain. The first indicators are from subsurface bore holes, and the second are the inland fossil cliffs.

Subsurface Indicators of SL Inundation.

From local bore hole observations, two possible shoreline localities have been identified. These are both well inland from the contemporary coast. The first locality has never received any scientific investigation.

1). The first locality is some 38 km inland from the present shoreline. (map ref., NZMS 260, V21 223647).

This site (Wenly Road - pers. comm., John Jones, Hill well drillers, Hastings) is some 75 m above MSL. The bore hole sediments include a near surface layer some 15 m thick consisting of blue clay and shell, and below this are greywacke gravels. There are no chrono-strategraphic date or data for this site.

2). The second possible shore line locality (pers. comm., John Jones, Hill well drillers, Hastings) is located to the west of Havelock North (Saint Georges Road, south) and is some 12 km inland. This locality may be coincident with the BROWN and GIBBS (1996) 6,000 y BP inundation limit and shore.

At this locality, there are three proximal sites (Saint Georges Road, south) at land surfaces some 10 m above MSL.

site A (408638) (map refs all NZMS 260, V21)
site B (404639), and
site C (405638.

Site A and site B have brown sediments composed of pumice, sand and gravel to a depth of 6.5 m; Site C has brown clay to a depth of 3.9 m.

Below these depths the sediments are mostly blue clays with gravels with shell and sandy layers, with thin hard layers of brown clays.

The environment of the first locality (1) is likely estuarine and the second (2) suggests an estuarine - coastal environment.

Inland Fossil Cliffs. (map ref Taradale, NZMS 260, V21 388778; Tangoio V20 495005; Pakipaki V21 355609)

Fossil sea cliffs extend between Taradale and Tangoio. At Tangoio the fossil cliffs pass into modern cliffs. There are also possible fossil sea stacks, for example Pakipaki and off shore islands, for example Napier's Scinde Island. At this time, 7,500 y BP, CARTER, CARTER and JOHNSON (1986) put the SL at - 9 m for the east coast of the South Island.

It was only after the SL is thought to have stabilised some 6,500 y BP that sedimentary progradation began to infill the large estuary with mostly muds with interbedded silts and sands with associated vegetation and "a succession of beach gravel and sand deposits" accumulated (BROWN and GIBBS, 1996).

4.0 Implications for Sea Level Alteration and Mixed Sand and Gravel Barrier Evolution.

International literature contains examples of paraglacial coastal mixed barrier genesis and geomorphology and the importance of SL, for example FITZGERALD and ROSEN (1987); JENSEN and STRECHER (1992); ORFORD et al., (1991). Also important are the barrier architecture (FORBES, et al., 1995) and antecedent configuration and basement geometry (ORFORD, et al., 1995) and the relationship to fixed hard rock promontories (FITZGERALD and ROSEN, 1987). It is also considered that SL alteration can force changes of tidal amplitude by changing a basin geometry (FORBES and TAYLOR, 1987).

The SL can exist in one of three cycles, ignoring transitional stages, where these are an increasing SL, a still stand, or a receding SL. For coarse sedimentary barriers the literature contains examples of what may be expected under these prevailing SL conditions. Most of the literature concerns a rising SL, with some information on a receding SL.

Sea Level Increase.

FORBES and TAYLOR (1987) demonstrate the paraglacial coastal geomorphic response can depend upon the relative rates of SL increase. As a generalisation, the evolution of mixed sand and gravel barriers follow a fairly well defined path. As the SL rises so terrestrial glaciogenic sediments become susceptible to erosion and release into the coastal environment (namely the littoral zone). If the release of sediment is large then a barrier can form and prograde seaward.

Barrier progradation can be characterised as beach width increase from overwash deposition without beachface recession, or as beachface progradation with multiple storm ridge morphology. Under a rising SL, the younger seaward beach crest ridges are topographically higher than the older inland beach ridge crests.

Such a barrier system can evolve under a rising SL as barrier migration, especially where the glaciogenic sediments are sufficient and are progressively available to erosion as the barrier migrates (FORBES et al., 1995). A barrier can also back step and migrate inland as water levels rise (ORFORD, et al., 1991).

SL rise can overstep a barrier and with rapid sediment deposition preserve well defined geomorphic structures as traces on seismic profiles (JENSEN and STRECHER, 1992), or can alter the tidal inlet dynamics producing flood deltas, reducing the barrier width and an eventual destruction of the barrier (BOYD, et al., 1987).

Sea Level 'Stabilisation'.

As the SL rise stabilises and reaches a still stand so the availability of the terrestrial glaciogenic sediments can decrease. This is illustrated where the degraded terrestrial material (regolith) at a coast is eroded exposing a hard rock surface so that the quantity of available regolith decreases.

In the case of a mixed sand and gravel barrier the beachface surficial sediments can rework. This reworking suggests the barrier becomes cannibalistic and recycles gravels. This recycling is considered to have two characteristic measurements. The recycling reduces the angularity and size of the more easily abraded clasts. These gravels become more mature with rounding in a longshore direction. The second measure is observed as the sediment textural alterations across a characteristic geomorphology, for example an increase of sediment sorting on the ridges, and cusps.

The evolution of a barrier under a 'stable' SL depends upon the sediment supply. With a dwindling availability of sediment a barrier may start to stretch and eventually break up and, or, alter the planform from a swash to a drift alignment (CARTER and ORFORD, 1991).

Sea Level recession.

Where the SL recedes FORBES and TAYLOR (1987) suggest three possible outcomes. Firstly, the beach crest ridges become perched above the hydrodynamic zone as "flights" of abandoned storm ridges. Secondly, with an abundant sediment supply, the nearshore can have sheets of sedimentary deposits across the littoral substrate. Thirdly, with small quantities of sediment supply the geomorphology becomes relict above SL and may show regressive or transgressive characteristics.

5.0 The Hawke Bay Barrier Genesis and Evolution and Sea Level.

For the South Island east coast, the SL is thought to have reached MSL some 6,000 y BP. However, this 6,000 y BP culmination was possibly with an amplitude of +2 m before receding towards the present SL. This recession took place over a period of some 2,000 y (SOONS, et al., 1997; SHULMEISTER, et al., 1993). It was over this 6,000 y period that the South Island barrier is thought to have evolved (SHULMEISTER and KIRK, 1993; 1997). OTA, et al. (1988) support the 2,000 y recession and place the formation of the northern HB lagoons at about 4,000 y BP with the formation of a sandy barrier, post dating the +10 m 6,000 y BP culmination for the east coast of the North Island.

The HB SL curve (Figure 1) indicates one major oscillation of SL some 8,000 y BP (BROWN and GIBBS, 1996), or perhaps two oscillations some 8,500 y BP and 7,200 y BP (GIBB, 1986).

The geological evidence suggests the HB SL has risen above MSL and has receded, perhaps twice:-

1). From some +10 m above SL, some 6,000 y BP (OTA, et al., 1988), and

2). Possibly again from some +5 m some 1,200 y BP (BROWN and GIBBS, 1996) and has possibly since receded to the present MSL.

This does not include the coastal deposits at Wenly Road some 38 km inland and some 75 m above MSL. It is suggested that the Wenly Road site may represent the W3 surface, some 120,000 y BP (LEWIS 1971), of the Kaihinu interglacial. In this instance, this site may support the LEWIS (1971) suggestion of a vertically tilting inner HB.

The Observed Hawke Bay Barrier.

The following can be observed along the modern coast.

It is proposed to explain the contemporary HB geomorphology on the two identified SL oscillations,

1). 6,000 y BP, and

2). 1,200 y BP.

It is evident that an abundant quantity of sediment from the Cape has been available for a barrier system to form in HB. It is also likely that the longshore drift towards the north has not altered within the Mid-Late Holocene time period, where this can be deduced from the benthic sediment textural distributions (see PANTIN, 1966).

The 6,000 y BP Culmination of SL.

This is split into an early and a late part of the SL +10 m amplitude.

In this early stage of barrier evolution with a rapid rise of SL (estimated to be some 10 mm/y between 8,500 y BP and 6,000 y BP for the South Island east coast (SHULMEISTER and KIRK, 1993) it is most likely that a proto-barrier began as a fringing barrier at the base of the Cape cliffs, and possible the simultaneous establishment of geographically widespread cliffs and islands. Indeed, at Clifton a raised (or perched) fossil barrier can be observed as a series of ridges forming a wide fringing barrier at the base of the inland cliffs. Between Clifton and Te Awanga, these fringing composite ridges are truncated by the Maraetotora River flood plain, but the ridges appear again inland at Te Awanga where they are also backed by a cliff. However, north of Te Awanga the cliff slopes and dives beneath the ground level, leaving a series of gravel ridges without an inland cliff. These cliff-less ridges continue to Haumoana. A similar cliff-less gravel ridge sequence could be found at Awatoto but since buried using building waste by Napier City Council for beautification.

The cliff-less gravel ridges suggest the possibly culmination of SL at the 6,000 y BP maximum amplitude of some +10 m. This may also include the Awatoto ridges. The areal extent of this early barrier between Clifton and Haumoana suggests swash orientated extension by progradational spits, and if Awatoto is contemporary then it suggests large quantities of sedimentary material may have been available for transport to extend across the Clive muds.

In later stages with a falling SL (6,000 to 4,000 y BP) the barrier may have become cannibalistic with large scale periodic reworking of the sediments. This reworking process would have taken place during large storm events. It is suggested that this late period saw the formation of many of the seaward ridges at Clifton, and between Te Awanga and Haumoana, and possibly Awatoto by a process where sand is selectively removed in storms leaving a gravel ridge (SHULMEISTER and KIRK, 1997).

The perched barrier ridges between Clifton and Te Awanga were possibly destroyed when the Maraetotora River changed coarse, probably by tectonic faulting causing a diversion. The Maraetotora then flowed north to the present HB shore. The area subsequently became a relatively wide flood delta plain without any trace of previous barriers. This flood plain has on occasion supported worm burrowed estuarine light grey muds and thin black organic soils. The estuarine conditions suggest partial isolation from the open sea, possibly by a single MSG barrier spit, not unlike the present day Tukituki River inlet lagoon.

The 1,200 y BP Culmination of SL.

This is also split into an early and a late part of the SL +5 m amplitude.

It is suggested the early 1,200 y BP SL rise would have initiated a second series of progradational spits and the formation of seaward barrier ridges observed and distinguished by a different planform arcuate orientation to the earlier (6,000 y BP) inland set. It could be expected that a SL rise could increase the available weathered material from the Cape and increase the supply. The supply increase could result in an increase of the height of the seaward ridge. Hence, a characteristic of the 1,200 ridge is a greater topographic height than those immediately to landward.

Representation of these (1,200 y BP) ridges are readily observed along the modern barrier and appear to be either welded onto the 6,000 y BP multiple ridge barrier, or as a stand-alone ridge.

At Clifton, this single (1,200 y BP) barrier truncates all of the previous barrier ridges along their seaward margin. The 1,200 y BP barrier is characterised by a single ridge between Clifton and Te Awanga, it is transgressive, passing landward across the Maraetotora delta although there are fossil inlets that tend to act as conduits for the overtopping high seas. The transgressive character of this ridge is evident by the insitu swamp vegetation exposed on the beachface (Section 3.2; Figure 3.3).

In Te Awanga this single barrier ridge lays across the Te Awanga reef where it is broken by the modern Maraetotora inlet. North of Te Awanga, this ridge is observed to blend into former ridges before reaching Cape View. However, north of Cape View the ridge is again characterised by a massive solitary seaward feature fronting Haumoana.

The solitary ridge is broken by the Tukituki River inlet but continues north across the Clive muds, to be broken again by the Ngaruroro River inlet before welding onto the former Awatoto barrier ridges. Indeed an old map (pers comm., Brian Gestro, Napier City Council. Map held at HBRC) shows an inshore parallel en-echelon chain of islets at Clive.

Towards Napier, the single ridge is possibly incorporated within the Marine Parade spit. It is suggested that this 1,200 y BP barrier extended by alongshore progradation so that the Marine Parade barrier eventually connected to Scinde Island. This suggests a relatively young age for the Marine Parade barrier.

6.0 Discussion on the Hawke Bay Barrier Genesis and Sea Level Alteration.

The early genesis of the HB barrier is considered to follow the FORBES and TAYLOR (1987) model with an initial rising SL and an abundant sediment supply. The initial rise in the 6,000 y BP SL is followed by a SL recession resulting in a flight of abandoned storm ridges.

The perched gravel ridges, especially at Clifton may not be all entirely due to a receding SL. It is possible tectonic activity has uplifted both the Cape Kidnappers and the fringing gravel ridges at Clifton and Te Awanga. LEWIS (1971) has suggested that tectonic uplift has enabled the preservation of these coastal barrier beach ridges.

7.0 Excavation Observations.

Down hole logs along the coast are geographically restricted with very few along the barrier between Clifton and Te Awanga (no commercial water) with a few between Te Awanga and Cape View (hope of finding fresh water). Over the study period two excavations were made with one at Te Awanga and several at Clifton. Both these excavations contained gravels with varying quantities of shell material that was collected and sent to and identified by Alan Beu, GNS (Appendix 2.1).

The excavations are Clearview (Te Awanga) for wine cellar foundations, and Angus's Cafe, Clifton for planting mature trees. The Clifton excavation contained abundant shell material from the most inland excavation. From observations, the sediments range from fine gravels (largest medium gravel) at Clifton to coarse gravels (largest cobbles) at Te Awanga.

Clearview Winery, Te Awanga, (Clearview Winery, NZMS 260, W21 507674).

A large gastropod test was found in situ in a subsurface (approx 1.5 m below ground level). The site represents the seaward slope of a perched beach ridge, and possibly the toe of a beach face, some 4 m above MSL and 350 m inland from the contemporary barrier beachface shoreline.

Angus's Cafe, Clifton, (W21 533663).

These excavations were some 80 m inland from the contemporary shoreline and exposed three perched gravel barrier ridges. Alongside the inland excavation a spoil heap with a thanatocoenosis of marine gastropods was found with some whole tests. It is thought that these came from some 2 m below ground. This site is considered to represent an overwash deposit and the locality is a Holocene terrace at + 4.5 m (MSL) identified by LEWIS (1971) and fringes inland fossil cliffs.

Excavation Implications.

These excavations indicate that the Cape Kidnappers has supplied sediments to the coast and in sufficient quantities to form a barrier. The shell material is representative of a marine - estuarine environment. The overwash deposition suggests storm-induced transport of seabed sediments. It is thought (pers comm., Alan Beu, GNS) the fossil assemblage is representative of rocky marine and clastic estuarine substrates and climatically similar to that of modern Wellington.

8.0 Conclusions.

For a barrier to develop there are three necessary factors (i) the sediment supply, (ii) SL and (iii) wave climate where all three require coincidence. Also important is the direction of longshore transport (by wave climate) that must be consistent over a long time (megascale to macroscale).

The HB barrier genesis is considered to follow a model proposed by FORBES and TAYLOR (1987) with an abundant supply of sediment and a rising SL culminating at a high SL before a recessive SL and a decrease of sediment availability that has led to a reworking of the existing barrier. There is evidence of regional SL rise (OTA, et al. 1988; CARTER, CARTER and JOHNSON, 1986) and local SL rise with oscillations (BROWN and GIBBS, 1996). Upon these there is evidently a tectonic component (LEWIS, 1971).

For HB it is suggested there are two episodes of SL rise and recession as indicated by the barrier ridge geomorphology. The two episodes are:-

1). 6, 000 y BP, and

2). 1,200 y BP.

The 6,000 y BP Barrier.

The geomorphologic evidence suggests the early barrier built against cliffs and extended north and may have crossed the Heretaunga Plain. This barrier has multiple ridges sub-parallel to the modern coast. The geological evidence suggests a rise of SL and culminating still stand and the erosion of headlands to form cliffs. Over a period of time successive deposition and extension alongshore led to the formation of a series of ridges possibly by spit extension towards the north. This northerly direction suggests a fairly uniform directional wave climate. The SL receded leaving the multiple ridge barrier perched above MSL, however for the southern Clifton portion tectonic uplift may have played a part in perching the barrier above MSL. Cross-shore and likely overwash deposition is evident from seabed fossil assemblages. The biological evidence shows an assemblage exhibiting members from a coastal environment typified by sandy beach, slightly deeper waters, and boulders in a muddy estuary. A gastropod sample (Te Awanga) indicates a rocky substrate, similar to the modern inshore environment.

The 1,200 y BP Barrier.

Evidence suggests some 1,200 y BP the SL may have risen to +5 m (BROWN and GIBBS, 1996). This SL rise could have eroded the Cape Cliffs at an increased rate with subsequent deposition to the north. This depostion may have led to the observed present day seaward beach morphology characterised by a single ridge that can be observed as either a stand alone feature, or welded onto the antecedent 6,000 y BP barrier. Where the single ridge has welded onto the multicrest barrier the topography is greater via a process of overtop deposition. Overwash deposition also occurs accompanied by the reworking of the beachface sediments, for example, exhumed gravels become incorporated within an overwash event and redeposited to landward. Between Clifton and Haumoana the beach is erosive and actively reworking the antecedent 6,000 y BP sediments. Further evidence of the transgressive nature of this single ridge can be observed between Te Awanga and Clifton where overstepped swamp plants and muds are visible on the modern beach. Given the modern steady state still stand the present day transgressive nature can be partially explained by 'erosion' where this could be a function of the decline of sediment supply, notably from Cape Kidnappers.

Invariably the response of the barrier to a SL alteration also appears to depend upon the sediment supply and texture. As the sediment supply decreases then the barrier can become sediment starved and begin to decrease in width.

It is indeed likely given the HB tectonic setting that the relative SL alongshore differs, where some lengths of coast are 'subsiding' for example Clive, (here the relative SL is transgressive and advancing). Other lengths of coast are subject to sudden tectonic event, for example Scinde Island, or a gradual tectonic warping, for example Clifton and Te Awanga.

APPENDIX 2.1

Fauna Indentification.

From Alan Beu, GNS, Lower Hutt.

Letter 13 December 2000.

(a) Large gastropod from Tim's winery, Clearview (W21 508673: 176° 58.7', 38° 38.1'):

Argobuccinum pustulosum (Lightfoot), this is a carnivorous, hard bottom species that appeared in New Zealand (probably) during oxygen isotope stage 7; very interesting for my research.

(b) 'kitchen paper set'. from Clifton (W21 533662: 177° 00.2', 38° 38.6'):

Bivalve: *Spisula aequilatera* (Reeve), 1 good valve-sandy ocean beach,

Caryocorbula zelandica, 2, slightly more offshore in a variety of habitats,

Gastropoda: *Trocus (Coelotrocus) tiaratus* (Hutton), 2, shallow, sandy beach,

Maoricolpus rosecus, 1, broken and worn; wide range of shallow, sandy habitats;

?Cominalla sp,1, worn juvenile,

Xymene plebeius,1, boulders on estuarine mudflat;

Obviously, this is a very mixed lot, such as you might expect to accumulate in a bay bar, from estuarine, sandy beach, and shallow offshore environments.

(c) Fragments from the bottom, from Clifton

Bivalvia:*Ostrea chilensis* (Orbigny), one worn piece;

Ruditapes largillierti (Phillipi), fragments, c. 80% of sample-sandy beach species in sheltered embayments, not oceanic;

?Pernia canaliculus (Gmelin)("green-lip mussel"), one fragment;

Tawera spissa (Q&G), one fragment, worn;

3-4 bivalve fragments worn and leached, indeterminable.

A small pebble in this sample looks as if it might well be a very round piece of Te Aute facies limestone. This sample is dominated by *Ruditapes largillierti*, and so probably lived in shallow water (a few metres) in an embayment similar to Wellington harbour (where it is common now) such as Hawke

Bay at the time? The other taxa seem, again, to have been carried into the deposition site from a range of other environments. So again, it might well represent deposition in a bay bar.

Most of the fragments in this third sample have been severely abraded before deposition, including the oyster (*Ostrea*). Some of the others, notable the *Pernia* fragments (with a nacreous interior) and a couple of the indeterminable ones, are softer than the others and clearly have been leached in situ, whereas the others have not been leached.

Appendix 3

Historical Bathymetry Charts of Hawke Bay

APPENDIX 3.

Historical Bathymetry Charts of Hawke Bay.

DATE SURVEY		AREA SURVEYED	PUBLISHERS
1769	Captain Cook	Hawke Bay	Royal Geographical Society, London.
? 1837		Ahuriri and Ahuriri entrance	Hawkes Bay Gazette
1855	Captain Drury	Ahuriri and off Scinde Island and northern Marine Parade	Royal Navy Hydrographics Branch
1865	Mr. Bousefield	Ahuriri and off Scinde Island and northern Marine Parade	Surveyor
1873	Mr. Weber	Ahuriri and off Scinde Island and northern Marine Parade	Surveyor
1878	Mr. Weber	Ahuriri and off Scinde Island and northern Marine Parade	Surveyor
1882-1895		Ahuriri and off Scinde Island	Engineers of the Napier Harbour Board (plan 28).
1906	Mr. F. W. Marchant	Ahuriri and off Scinde Island and northern Marine Parade	Engineer of the Napier Harbour Board
1927		Hawke Bay	Royal New Zealand Navy
1954		Hawke Bay	Royal New Zealand Navy
1981		Hawke Bay	Royal New Zealand Navy

Appendix 4

Sampling, Bench Mark Positions, Gravel Sizes, ZINGG classification

SAMPLING HAWKE BAY GRAVELS AND MORPHOLOGY.

1.0

The Hawke Bay (HB) mixed sand and gravel (MSG) barrier was sampled to obtain three data sets. The first set was the sediment textural gravel component, the second set the beachface topography (topographic surface (3D) and transverse profiles) and the third set combined cross-shore transverse profiles with gravel sampling for specific 'events', namely a moderate and a high wave energy event. This outline firstly looks at the gravel sampling and secondly the topographic sampling (see Section 6.0). The Bench Marks (BM) sites are listed separately later in this appendix.

1.1 GRAVEL SAMPLES.

Gravels were sampled from the marine and the terrestrial environments. The Marine environment gravel samples, comprised the three sample sets, the Low Water, the moderate wave energy and the high wave energy. The Low Water (LW) gravel samples centered on cusp horns along the reworked LW ridge that rests upon the lower beachface platform. Later, gravels were sampled at specific morphologies for the specific high wave events. For the moderate wave energy event the gravels were sampled from the LW and High Water (HW) cusp horns (LW and HW ridges). During the high wave energy event the gravels came from across a high water ridge. Transverse cross-shore profiles were collected in conjunction with the wave event gravels.

Marine gravel sampling:-

1). From September 1997 to April 1998. The LW cusp gravels. The plan was to sample from a spring to an autumn equinox, however, from early February 1998 to late March 1998, the lower beachface was sandy and gravels were not present in sufficient numbers to sample. This sandy beach cover led to the sample set being split into two. The main body of the thesis uses a set from September to December 1997, whilst Appendix 7 has the 'complete' set from September 1997 to April 1998. The September to December samples were taken on average every 9 days. This long trend group included three high wave energy (H_b > 1.0 m) events. In total five sites were sampled, the Westshore sample set was discarded to constrain the study to the Cape Kidnappers to Scinde Island barrier length. The remaining four sites are Clifton, Te Awanga Hall, Haumoana and Marine Parade.

Rational. These LW gravels should show the greatest change, being in the most active (continual swash) environment. The rational for an extended sampling program was to test for any seasonal change that may take place at each site, and to find what changes take place in the longshore direction. Also, to measure the changes of textures associated with end members, namely 'events' ranging from long lacuna of low wave energy to the short time event associated with high wave energy. It was thought that the gravels may 'drift' towards some common state during these 'events'. And, these data are not related to the beachface platform slope.

2). High wave energy events. Two events were measured, firstly:-

Moderate wave energy event (H_b ≈1.5 m) as soon after this event as possible. This was a 'pulse' event. Before this pulse the wave heights and breaking wave steepness were low. The event was marked by a sharply rising sea of long wave period and wave height. The event turned out to be 'erosive' at all sites except Marine Parade which was depositional.

Samples, (i) gavels sampled 28 September 2000 at the LW and HW positions synchronously at 4 sites; (ii) transverse cross-shore profiles before 15 August 2000, during 25 September 2000, and after 12 October 2000 the event at the 4 sites, and (iii) wave data over the period from 20 September 2000 to 14 October 2000.

High wave energy event ($H_b \approx 2.0$ m to 2.5 m) as soon after this event as possible. This was a long swell wave group. The before waves were of low height and steepness. The onset was marked by a rapid gain of wave height and steepness which persisted for some 10 days ($H_b > 1.5$ m). This turned out to be a HW ridge depositional event.

Samples, Te Awanga, (i) gravel samples on 3rd and 6th June 2000 at three sites across the HW ridge; (ii) transverse cross-shore profiles before 16 May 2000, and after 9 June 2000 the event, and (iii) wave data over period from 16 May 2000 to 10 June 2000.

The rational was to sample specific events to measure the characteristics of the wave energy and beachface slope associated gravel populations.

The terrestrial gravel samples.

Three sample groups. Firstly the contemporary river, secondly the Cape Kidnappers debris, and thirdly the stratigraphic column near the inland Ruahini Ranges.

1). The Tukituki River is the only river coarse linking the greywacke gravel source, the Ruahini Ranges, to the modern coast. It was possible to repeat sample the river coarse at two localities downstream, (Waipawa and Red Bridge) first in 1988 and later in 1998. The data for the gravel fractions include WHITE (1988) and this study.

2). The Cape Kidnappers is a recognisable supply of gravel to the marine environment via cliff fall and deeply incised gully washout from the conglomerates. These conglomerates are also mostly fluvial deposits derived from the emergent inland Ranges. Therefore, the Cape conglomerates have a modern supply component and are also a measure of an ancient geological river deposit downstream from the Ranges.

3). The Ruahini Ranges have adjacent strata containing conglomerates derived from the emergent and tectonically active Ruahini Ranges. These strata should contain a record of gravel textural changes from the greywacke gravel source. Also the late strata are contemporary to the Cape Kidnappers conglomerates.

The rational for sampling the terrestrial gravels centered upon the unique situation to Hawkes Bay. The origin of the greywacke gravels is well defined in geological time starting when the Ranges uplifted some 0.5 m. y. ago. It is possible to sample the gravels within the stratigraphic column adjacent to the Ranges to measure any changes of clast form in geological time from a local source.

Since the tectonic uplift began, gravels have transported towards the coast. Gravels are available both from within the geological column near to and distant from the Ranges, and from the contemporary Tukituki River. Therefore, it is possible to determine the changes of gravel forms from two river supply systems using samples from both near source and distal from the source in (a) geological time, Pleistocene) and in relatively Recent time.

Finally, it is also possible to measure any change of gravel forms supplied to the modern coast from the two supplies, namely the Cape Kidnappers and the Tukituki River.

Alongshore beach site selection was based upon criteria, namely a morphodynamic evolutionary state recognised as initiation, establishment or breakdown (FORBES et al., 1995). The Haumoana site was negated by construction of a groyne.

2.0 Literature.

The literature is split into the previous HB gravel sample data and briefly, some examples of the techniques used in sampling methods. It is useful to be able to replicate sampling to compare the characteristics of similar clasts in similar environments.

In the early 1980's the Hawkes Bay Catchment Board and Regional Water Board gathered sediment samples from the barrier (unpub. data WILLIAMS, 1986) but these are not specific as to where on the beachface or the morphology where they were collected and the data are for size and weight only. MARSHALL's data (1928; 1929) are of clast size and weight they are not for clast form, nor are they geomorphic site specific. SMITH (1984) looked at the shape and form characteristics of clasts from the rivers and across the beachface, with N=100 clast in each sample. These samples are not site or morphology specific.

The literature on the techniques of sampling are mostly for fluvial beds and reflect either the surface grid method useful for parametric statistics (KRUMBEIN and MILLER, 1953), or the field technique of obtaining a good representative size distribution using a pre-sized template to measure clast sizes (FRIPP and DIPLAS, 1993).

The number of clasts to be sampled to be statistically valid is debatable (ORFORD, 1975). It is acceptable to be systematic in the sampling procedure at fixed distances both along and cross-shore with the most frequent sampling chosen to correspond with the spring tide zone to get maximum pebble segregation (ORFORD, 1975; SHERMAN, et al., 1993; WILLIAMS and CALDWELL, 1988). For morphological sampling SHERMAN, et al. (1993) sampled systematically across a cusp and at three depths at 0.15 m, 0.3 m and 0.45 m.

Sediment sampling demands a representative grain size weight distribution. For sandy sediments, the tails of the distribution curve have the most information (BALSILLIE and TANNER, 1999). In the case of a mixed sand and gravel textural sized beach the inclusion of a clast in a medium sand matrix would skew the coarse tail and become statistically (moment) significant, but the clast would fail to be representative, for example N=1 as a clast form parameter, where the requirement is N=40 for a non-parametric test (SWAN and SANDILANDS, 1995). The number of clasts in a sample is important when determining their mode of deposition, for example wave action on clast parameters across a modern gravel and sand beach (DOBKINS and FOLK, 1970). Incidentally DOBKINS and FOLK (1970) follow the ideas presented by MARSHALL (1928; 1929) based on observations of the gravel barrier here in HB. MARSHALL (1929) concluded the HB clasts are disc form because of wave active abrasion, based upon environment target sampling of a river and a beachface (the Tukituki River lower reaches and along the HB beachface towards the north).

3.0 Sampling the Hawke Bay Gravels.

Three sample categories were used depending upon the parameters needed (Table 1). There are many reasons for varying the number of clasts collected including the practicality of carrying large samples that sampling a grid pattern would require. The HB barrier sampling is specific and represents an easily recognisable morphotype, for example the horn of a cusp. This is possible for the contemporary beachface, but not for the palæo-environments where the processes of deposition are not entirely clear. For example, the palæo gravels can be stratified with a shell hash, but the depth of water and the conditions leading up to the deposition are not well known. Table 1 summarises the three sample categories showing the number of clasts collected, the environment of deposition (where known), the morphology (where known), the morpho-target (where known and a target morphology for repeat sampling over a period of time) and the energy of the prevailing depositional agent.

The greatest restriction on the number of clasts in a sample is their accessibility for example along a bedding plane in a stratigraphic horizon there can be very few clasts, or in a high seas event at a cusp horn there is little time between successive high energy breaking waves.

The smallest sample size is N=5 and these are for the five largest observable clasts. The minimum number of sample clasts required to be statistically valid ranges from 30 (WILLIAMS and CALDWELL, 1988), or 33 (ORFORD, 1975) to 40 (SHERMAN, et al., 1993) for the sizes of surficial clasts available, but 5 clasts are representative as a geological axiom (KRUMBEIN, 1942). This study is light of statistics since samples are small in number, and, as it turned out, the parameter distributions are not normally distributed (Gaussian), and this applies to gravels and beachface profiles.

4.0 Methods of Sampling the Clasts.

Two methods were used. Firstly repeat sampling from the same environment and secondly isolate samples.

1). The repeat samples are those from the most active part of the beachface namely the lower swash cusp horns. If possible, the samples were from all four alongshore sites in rapid succession to make them synchronous samples. The method was to sample each site at low water on the same day at and nearest to the transverse profile line(s). The number of clasts for each sample was the five largest and the next one hundred clasts within a maximum area of one square metre. A problem arose in the summer months when the lower swash sample sites became sandy. This occurred between February and early April 1998. If possible the sample was N=40, but became N=0 when clasts became few and isolate on a sandy beachface surface.

N	Environment	Morphology	Morph-target	
Energy				
105	lower swash	detached cusps	horns	high1
	river	longitudinal bars	mid length crest	high2
40	lower and upper swash	detached cusps	horns	high1
		attached cusps	horns	high1*
	palæo	a depositional surface nearshore usually with ripples or plain bed		storm?
	barrier	depositional surface	slurry slug	high3
5	various			

high1 - is near continuous high energy wave field, at low water

high 1* - energetic at the high water

high2 - is an episodic high energy in a flood event

high3 - is an episodic event of over wash

palæo is sample from stratigraphic sampling sites near Ruahini Ranges

Various - various other sites were visited in the coarse of this research.

Clasts sampled represent like lithology and known environment.

Table 1. The number of clasts sampled in Hawke Bay for the three categories representative of the i). Contemporary barrier; ii). Paleo gravels in the stratigraphic column, and iii). Highly active beachface events.

2). Isolate samples are from single visits to a site for example a rock exposure, or the samples are representative of a particular event, for example a high energy overwash sheet. Isolate sampling regime can be more relaxed since rock exposures and an overwash sheet will remain essentially the same for some time. Rock exposure samples were N=5, the largest clast, mainly because in some exposures the clasts were within a thin layer and few, for example in the Late Pliocene.

Determining the hydrodynamic effects on the gravels at the lower and upper swash zone during high breaking waves entailed specific sampling and the number of clasts was reduced to N=40. For sampling in very high seas at low water the sample was reduced to N=5.

On the contemporary barrier there are individual clasts that do not fit into the usual known methods of clast measurement and these were rejected. A typical example is a greywacke clast composed of different textural sandy layers which have selectively abraded so that the clast looks like a miniature butte, or a large rivet. Yet other clasts have a quartz vein, which has been severely leached, these to are rejected.

5.0 Methods of Measuring Clast Samples.

Both calipers and a mechanical balance are more reliable for use in the lab and in the field. Electronic instruments may be faster once deployed but are subject to power failures, discharging batteries, water, salt and wind disturbance. The only problem experienced with the mechanical instrument approach was the effect of wind on the balance beam, and if it rained the notepaper got wet.

The caliper design and method (pers. comm., Yaacor Nir) of measurement followed KRUMBEIN (1941(a)) with the measurement of the orthogonal non-intersecting tri-axial lengths for each clast. Also, 'measured' using a visual comparison chart was clast roundness (KRUMBEIN, 1941(b)) as it was rapid and could be applied in the field. In some cases the POWERS (1953) visual chart was also used as a comparator. However, these roundness data are not presented in this study.

Volumetric data by immersion in water was collected to find differences in density between the native beach gravels and between these natural gravels and a set of aluminium tracer clasts. There were small differences between natural gravels, even the argillitic and greywacke clasts. The aluminium tracers were not used but painted clasts were used. The paint used was road marker paint and the chrome yellow proved very good, in fact to good because the public would find them and remove them from the lower beachface and place them on the upper beachface to help me find them more readily. White road marker paint proved not so successful because the clasts coated in white Bryozoan could not be rapidly distinguished.

All clasts are measured for their tri-axial orthogonal lengths for their size (intermediate axis length, mm) and their form (long, intermediate and short axis lengths, mm) parameters, where these are the ZINGG forms (cited BARRETT, 1980), the blades, discs, rods and spheres, and the oblate prolate index (OPI) and the maximum projection sphericity (MPS) (DOBKINS and FOLK, 1970). The ZINGG form and OPI and MPS derivations are reproduced as a postscript at the end of this brief outline of sampling.

Measurements also included the clast composition (the textural matrix for example argillite, fine or coarse grained matrix greywacke and features, for example exosolution or pitting of the clast skin).

6.0 Topographic Sampling.

This section begins with a brief review of the literature concerning the use of the transverse cross-shore profile as a method representative of natural processes. This is followed by an outline of the history of the HB coastal data.

To view the smaller scale changes on the active beach face the topographic survey needs to be intensive (in space and time) and this also applies to the more simple method of profiling, for example SONU and YOUNG (1970) demonstrate that if a stochastic model is to be applicable then the semidiurnal sampling intervals need to be continuous for 500 days, or 16 months. The longest continual record is 180 days for a North Carolina beach composed of sand (SONU and YOUNG 1970).

For adequate data it is necessary to extend the beachface transverses profile into the nearshore and this logistically leads to two survey methods using land based and sea-borne survey equipment. Indeed AUBREY (1979) reports that three years of data failed to measure accurately the changes between mean low water and the 9 m isobath and this makes the seasonal fluctuations of sediment erosion/ accretion difficult to measure on a sand beach. For a MSG beach these potential sampling errors may be greater or less. For this study, it is assumed that the offshore profile remains essentially the same throughout the study period. In addition, the errors need not apply to HB because the wave break and water depth are different. The wave break is mostly plunger-surger at a well-defined line corresponding the lower beachface submarine step, and at Clifton and Te Awanga, the barrier rests upon a fixed submarine rock platform.

DEAN and MAURMEYER (1983) briefly discuss the assumptions that the profiling method incur with the main assumption being that the data is an actual representation of the natural processes that are taking place. These processes include the effects of a variable wave breaking criteria, the depth of effective motion of the bed sediments, the constancy of the profile, firstly by virtue of a type sediment responding to the incident wave of variable energy, and secondly that the new profile is autocorrelated to the previous profile. This autocorrelation leads to a response time where a profile change is a lag, for example, the recovery time after a storm may extend over a period of years.

However, the use of transverse profiling to measure the beachface profile and to collect gravel data is well established with SHERMAN, et al., (1993) who used nine 5 m interval profiles over a 40 m control distance and ORFORD (1975) who used seven profiles 122 m apart. Transverse profiling is a recognised method for the direct measurement of the beachface and by extending the data over a period of time obtain a picture of the change for example from a statistical forecasting perspective (AUBREY, 1979, LEATHERMAN and CROWELL, 1997) and for empirical estimates of sediment transport (HANSEN and LARSON, 1987).

Historic HB data has two sources. The Hastings District Council's first transverse profile is 1914 for the Clive coast. The Hawke Bay Regional Council (HBRC) (Survey Department) has cross-shore profile data from 1916 for Westshore. This first profile data is for the Westshore-Bay View gravel barrier when a railway line was built along the barrier crest to the north of Napier. DOSLI (Napier) have some historical coastal plans which are rare given that the fire following the 1931 Napier earthquake destroyed most public records. These plans were sent to the National Archives in Wellington following the closure of the Napier DOSLI office.

The longest monthly profile data for a MSG beachface in New Zealand is not known. In HB data is usually annual (HBRC). Shorter time interval data has been collected. For example, Gary Williams data are monthly over a three monthly period for a three-year period (HBRC data records). More recently, in 2002, HBRC attempted to gather transverse profiles at monthly intervals over a period of one year. This failed because of adverse high seas conditions. This monthly profiling exercise was again started in 2004 by HBRC contract surveyors.

Three-dimensional topographic survey is relatively new. Richard Jennings (pers. comm., 2000) has topographic survey data for Palliser Bay, lower North Island MSG beachface taken once a day at low water for a 30-day period. The morphodynamic changes are most distinctive. In HB, 3D topographic survey is a very recent method initiated by the author and later by the HBRC for the repeat topographic maps for the Haumoana groyne before and after emplacement. Other 3D topographic survey data exists for the Te Awanga and Waimarama (south of Cape Kidnappers) beaches. The Te Awanga beachface data was for gravel tracer experiments. The Waimarama data set is for a seawall construction, before and after. These data were lodged with the HBRC. The use of 3D topographic surveys using scanning laser is reported in the literature RIXON et al. (2003).

7.0 Methods of Topographic Sampling Hawke Bay.

There were two methods employed in HB, (1) for the 3D topographic surveys and (2) for the transverse profiles.

1). A total station Nokia Set 2B was used for the 3D topographic surveys and clast tracer positions. This information is discarded from this study. 3D topographic surveys were done at Haumoana before and after the groyne construction. This was in conjunction with the HBRC, all together there are two before and four after the groyne construction. There are also two topographic surveys for the Te Awanga beach. Both are base maps for experiments that include tracer studies. There are also topographic surveys, before and after the construction of the 'Ron Flowers' new northern limestone boulder seawall, Waimarama.

2). Six sites were chosen for the transverse cross-shore profiles in southern HB, where these coincide with the gravel sampling sites, Clifton; Te Awanga Hall; Te Awanga K2; Haumoana; Marine Parade, and Westshore. Profile data was collected from May 1998 to August 2003. Within this period, and used in this study, is a three year data set of monthly profiles from June 1998 to May 2001. The data was the vertical height and the distance across an active beachface. For the vertical height a Level and Sopwith Staff were used and for the cross-shore distance a 6 mm polypropylene rope marked off with alternating colour tape at ten metre intervals. The marked off rope allowed for the rapid measurement of the vertical heights at 'constant' fixed distances from a BM. The rope markings also allowed the rapid measurements of vertical height to be obtained rapidly especially at the lower beachface in high-energy seas (H_b up to 1.5 m to 2.0 m). Constant fixed cross-shore distances were used at each site. This meant the vertical height changes at each cross-shore position can-be related over time. All six sites were profiled synchronously. Synchronous sampling was in a short time span – across two days with the two Napier profiles Westshore and Marine Parade on day one and the Haumoana to Clifton profiles on day two. The following profile set would be done in reverse, so the first data set, day one, would be collected from Clifton to Haumoana and on day two the Marine Parade to Westshore data. Because profiles are synchronous and have fixed cross-shore distance data it means comparison can be made between profiles at select cross-shore distances, for example the HW ridge, for specific events.

Because the time for sampling in high seas at a number of sample sites is limited, it was not feasible to synchronously sample profiles and gravels. It would also have meant carting a great weight of samples leaking salt water in an unsuitable vehicle.

When sampling the transverse profiles extra categories of data were collected if present. These could include:-

1). Vegetation, including the 'terrestrial live' vegetation and the high seas debris strand lines.

2). Sediment texture, with boundaries between sand and gravel and notes of the sizes of the gravelly textures.

3). Water - where data are the water depths at the time of sampling (when able to), the low and high tide water levels via strand lines on the beachface, the water drift direction and the wave period, and height.

4). In high seas, the beachface morphology-cusp interval, height, and type (attached, detached, symmetric, asymmetric).

8.0 Human Impacts.

There were problems and these continue to get worse when undertaking field survey work. A prime example, the physical impact by people on the coast. The impact of humans is greater on the barrier morphology and gravel distribution patterns than natural events. This is contrary to the popular view held in New Zealand that natural events are far more destructive to the natural environment than humans. Natural events are far less frequent than the use of the beachface for recreation or own ends (for example beautification or personal dwelling 'protection'), or by local government for 'purposes' where these purposes are voter driven, and are strongly skewed by personal desires In very recent times, beachface changes occur that include fracturing of clasts by vehicles and horses (this included chrome yellow clast tracers). The surficial clast orientations and imbrications are destroyed and further, the morphology. It is possible the beachface surface disturbance is akin to increasing the bed roughness, therefore increasing erosive turbulent flow and hence bed mobility. Humans are accelerating clast attrition and likely bed mobility, they destroy natural surface distributions. Features of 'relict' bedforms that can be identified by lichen are also destroyed.

Material is strip mined off the Te Awanga beachface for local stop bank construction to protect the 'community' from river flooding by the HBRC. The far greater frequency of flooding is the high seas overtop. There is an increase of drainage diversion and new storm water outlets without regard to the water table by HDC, and is ultimately for greater urbanization. All has occurred and at an increasing rate since the introduction of the Resource Management Act, and especially since the introduction of the New Zealand Coastal Policy.

The data from either the 3D or a transverse profile survey can also be used to determine the anthropogenic impact upon the beachface. The human interference on topography, especially in the summer months reduced the number of useful profiles for ORFORD (1975). In Hawke Bay, the impact of humans remains unacknowledged by the local governments and populace. They want the natural beauty but are busy destroying it. It is important to note this.

Hawke Bay Mixed Sand Gravel Beach Profiles Bench Mark Positions.

CROSS SHORE PROFILE SITES ARE:-
Clifton
Te Awanga
Haumoana
Marine Parade, Napier

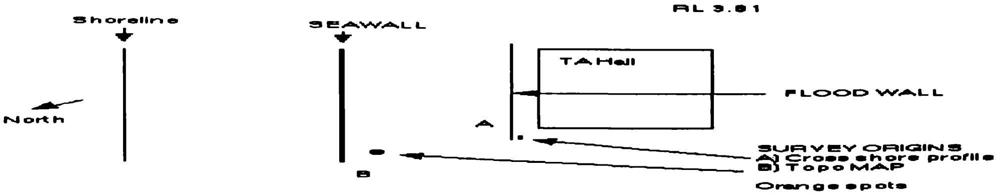
RL=Reduced Level relative to MSL (m) (Napier Port)

CLIFTON

Map Ref Topo Sheet W21 533664. DOC Sign Board
39° 36.5' 177° 00.3'
RL 3.34

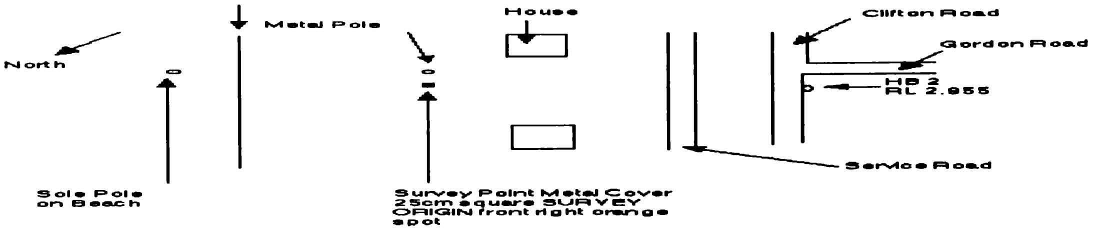
TE AWANGA

MAP REF Topo Sheet W21 515872
39° 38.10' 176° 58.8'
RL 3.81



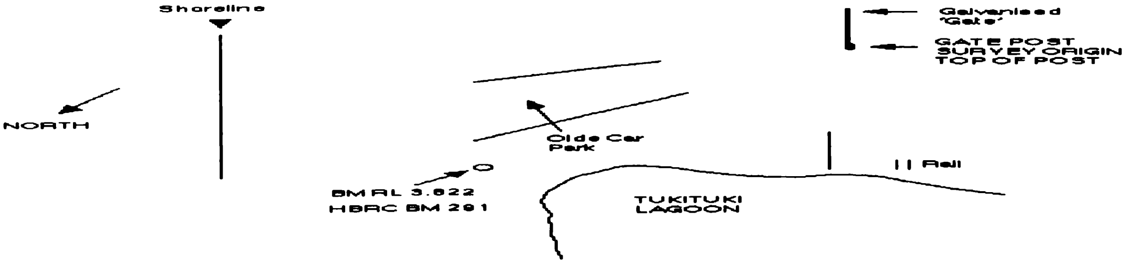
TE AWANGA GORDON ROAD K2

Map Ref W21 Topo Ref 513674
39° 37.9' 176° 56.7'
RL 3.73



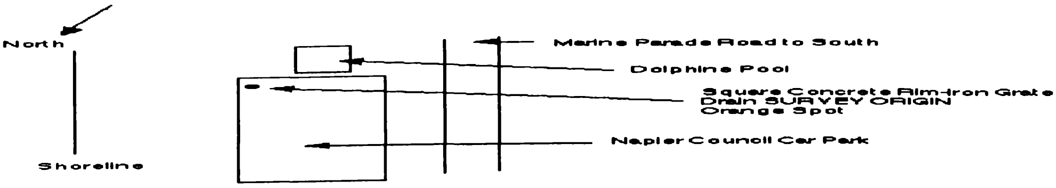
HAUMAONA.

Map Ref Topo V21 489709
39° 36.01' 176° 57.25'
RL 1.99



MARINE PARADE

Map Ref Topo V21 471829
39° 29.5' 176° 54.9'
RL 5.710



GRAVEL SIZES

Size	cm	Phi
BOULDER	12.8 to 25.6	-7.0 to -8.0
COBBLE	6.4 to 12.8	-6.0 to -7.0
Large VERY LARGE	4.8 to 6.4	-5.5 to -6.0
Small VERY LARGE	3.2 to 4.8	-5.0 to -5.5
Large LARGE	2.4 to 3.2	-4.5 to -5.0
Small LARGE	1.6 to 2.4	-4.0 to -4.5
Large MEDIUM	1.2 to 1.6	-3.5 to -4.0
Small MEDIUM	0.8 to 1.2	-3.0 to -3.5
Large SMALL	0.6 to 0.8	-2.5 to -3.0
Small SMALL	0.4 to 0.6	-2.0 to -2.5
Large VERY SMALL	0.3 to 0.4	-1.5 to -2.0
Small VERY SMALL	0.2 to 0.3	-1.0 to -1.5

(WENTWORTH size scale (ANDREWS, 1982))

ANDREWS, P.B., 1982. *Revised guide to record field observations in sedimentary sequences* . Report NZGS 102, Department of Scientific & Industrial Research, Lower Hutt, New Zealand. 74 p.

Maximum Projection Sphericity (SNEED and FOLK, 1958)

$$\sqrt[3]{\frac{S^2}{L.I}}$$

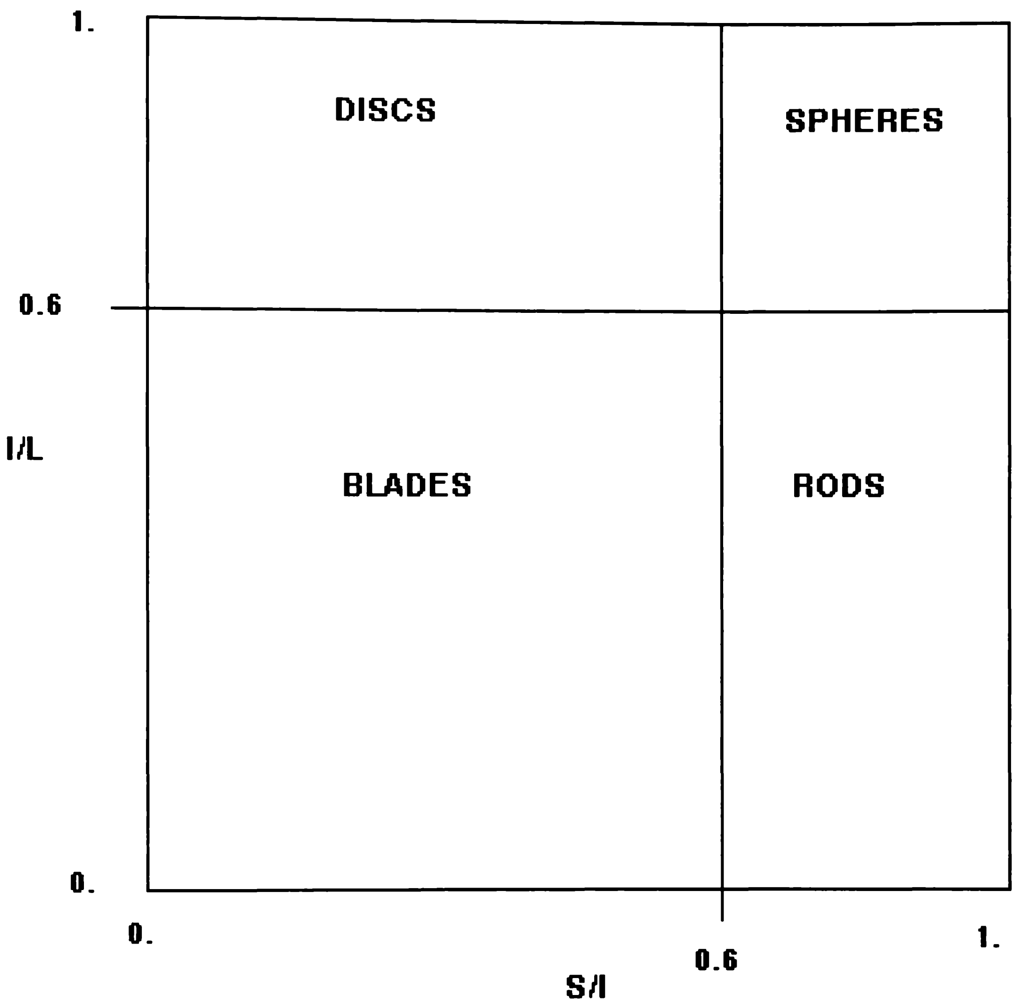
where
Axis lengths (mm)
L is Long
I is Intermediate
S is Short

Oblate - Prolate Index (DOBKINS and FOLK, 1970)

$$\frac{10.\left(\frac{L-I}{L-S}-0.50\right)}{S/L}$$

where
Axis lengths (mm)
L is Long
I is Intermediate
S is Short

ZINGG CLAST FORM CLASSIFICATION



Axis Lengths (mm)
L long axis
I Intermediate axis
S Short axis

ZINGG (1935) cited BARRETT, P.J., 1980. The shape of rock particles, a critical review. *Sedimentology*, 27, 291-303.

Appendix 5

Verbal Description for the Hawke Bay Gravel; Size, Skewness, and Sorting Parameters

VERBAL DESCRIPTION FOR HAWKE BAY GRAVEL SIZE SKEWNESS AND SORTING PARAMETERS

SKEWNESS		SORTING	
+1.0		4.0	
	strongly fine skewed		very poorly sorted
+0.3		2.0	
	fine skewed		poorly sorted
+0.1		1.0	
			moderately sorted
0.0	symetrical	0.71	
			moderately well sorted
-0.1		0.5	
	coarse skewed		well sorted
-0.3		0.35	
	strongly coarse skewed		very well sorted
-1.0		0.0	

Skewness (verbal descriptions based on FOLK (1968))

moment measures (GARDINER and GARDINER, 1979)

Appendix 6

Wave and Tide Summary for Gravel Sampling Period, and Textural Gravel Size Parameters Summary

Wave and Tide Summary For Gravel Sampling Period.

Sample period 24 August 1997 to 12 December 1997 (+ sample dates; * high seas)

Date	Period (T_b) s	Wave Height (H_b) m	Notes
24 Aug 1997+	13	3.5	
20 Sept +	12	0.6	decreasing wave energy
27 Sept +*	12	1.0	increasing energy, reworking beachface Westshore renourished with Marine Parade gravels
1 Oct	12	1.0	
6 Oct +	10	0.3	wind wave T=3 s, H=0.2m. Vaneer cusp on fines
16 Oct	16	0.4	
18 Oct +*	12	2.0	swash limit at Westshore renourishment toe, therefore source
2 Nov +	12	0.4	wind wave T=3s, H=0.3m Clifton renourished river gravels
14 Nov	11	0.4	
16Nov	7	0.3	
17 Nov +*	7	0.3	long period low wave height, therefore tidal reworking
25 Nov +	12	0.5-1.0	reworking of previous tidal sap
2 Dec +	10	0.3	increasing wave energy; vaneer cusps
8 Dec	7	0.5-1.0	
10 Dec	12	1.0	
12 Dec+ *	12	1.0	reworked high water gravels
31 Jan 1998	10	0.3	decreasing energy
1 Apr	10	0.6	increasing energy
25 Apr	14	1.0	decreasing energy from Hb=1.8 m

(Information from John White, Notebooks,
Sea, Sediment, Film log)

Tides

	Height (m)		
Date	Min	Max	
20 Sept	-0.1	1.8	high springs
27 Sept*	0.3	1.4	neap
6 Oct	0.3	1.5	neap
18 Oct *	0.0	1.8	springs
2 Nov	0.4	1.6	neaps
17 Nov	0.0	1.8	springs
25 Nov	0.4	1.5	neaps
2 Dec	0.3	1.6	springs
12 Dec*	0.2	1.7	springs

* high wave energy event (H_b> 1.0 m)

NEW ZEALAND NAUTICAL ALMANAC, 1997-1998. *Land Information New Zealand*, GP Publications, Wellington. 200 p.

TEXTURAL GRAVEL SIZE PARAMETERS

SUMMARY

Lower Beachface detached cusp horns.
Sample Sites are C=Clifton; T=Te Awanga Hall; H=Haumoana; MP=Marine Parade. Columns are from left to right Mean Grain Size (mm); Mean Grain Size (PHI); Sorting (standard deviation) (PHI); Sorting Coefficient; Variation; Skewness. End column is date of sample (day/month/year).

NaN is no data

```
C=[
17.604 -3.941 0.7063  0.1792 0.4988 -0.8025              %20/9/97
19.969 -4.077 0.7876  0.1932 0.6204 -0.7776              %27/9/97
15.048 -3.595 0.9126  0.2539 0.8329 -0.4448              %6/10/97
20.911 -4.205 0.7149  0.1700 0.5111 -0.2276              %18/10/97
12.217 -3.258 0.9197  0.2823 0.8459 -0.85                %2/11/97
17.844 -3.990 0.6313  0.1582 0.3985 -1.2450              %17/11/97
19.836 -3.929 1.1189  0.2847 1.2519 0.35                 %25/11/97
18.991 -4.015 0.7438  0.1853 0.5532 -1.03                %2/12/97
13.576 -3.258 0.9245  0.2838 0.8547 -2.31        ];      %12/12/97
%20.997 -4.018 1.0426  0.2595 1.0871 -0.1577                    %31/1/98
%14.900 -3.668 0.7752  0.2114 0.6010 -0.622];                    %25/4/98


T=[
%18.850 -4.136 0.5303 -0.1282 0.2812 -0.3413                    %13/9/97
19.669 -4.158 0.6196 -0.1490 0.3839 -0.3665              %20/9/97
17.397 -3.818 0.8230 -0.2155 0.6773 -1.1843                     %1/10/97 T=12 Hb=1.0
30.376 -4.840 0.4855 -0.1003 0.2358 -0.4187              %6/10/97
%35.183 -5.019 0.5602 -0.1116 0.3138 -0.8693                    %16/10/97 T=16 Hb=0.4
12.630 -3.486 0.6479 -0.1858 0.4198 -1.1742                     %18/10/97 T=12 Hb=2.0
27.515 -4.612 0.6913 -0.1499 0.4778 -0.3159              %2/11/97
21.119 -4.173 0.8047 -0.1928 0.6475 -0.1094              %17/11/97
19.053 -3.891 1.077  -0.2768 1.1601 0.3875               %25/11/97
31.341 -4.871 0.5400 -0.1109 0.2916 0.1751               %2/12/97
15.024 -3.519 0.9795 -0.2783 0.9595 -0.8706 ];           %12/12/97
%13.247 -3.317 0.8750 -0.2638 0.7657 -2.1154             %31/1/98
%28.467 -4.631 0.7964 -0.1720 0.6343 0.6473              %2/4/98
%16.686 -3.558 1.1641 -0.3271 1.3550 -0.5920];           %25/4/98
```

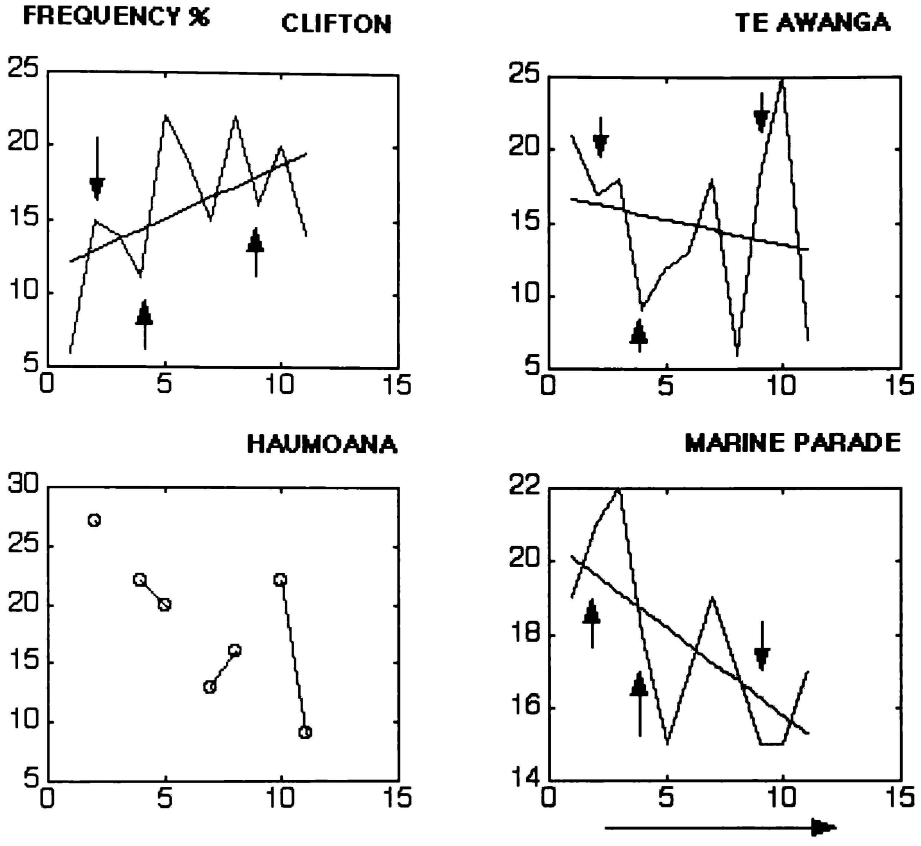
```
H=[
NaN     NaN     NaN NaN NaN NaN                                    %would be 20/9/97
19.217 -4.065 0.7324 0.1801 0.536 -0.451                           %27/9/97
NaN     NaN     NaN NaN NaN NaN                                            %would be 6/10/97
20.041 -4.294 0.2971 0.2129 0.0882 -0.241                          %18/10/97
6.288  -2.373 0.8245 0.3474 0.6798 -0.9796                         %2/11/97
NaN     NaN     NaN NaN NaN NaN                                            %would be 17/11/97
13.619 -3.485 0.9209 0.2642 0.8481 0.1473                          %25/11/97
18.369 -3.969 0.8347 0.2103 0.6968 0.3024       %];                %2/12/97
NaN     NaN     NaN NaN NaN NaN                                    ];      %would be 12/12/97
%16.960 -3.936 0.5554 0.1411 0.3085 -2.1726                        %31/1/98
%19.865 -4.169 0.5796 0.1390 0.3359 -1.4611];                      %25/4/98


MP=[
13.874 -3.636 0.623 -0.1714 0.388 -1.036                    %20/9/97
12.531 -3.495 0.604 -0.1727 0.364 -1.251                    %27/9/97
12.916 -3.484 0.722 -0.2074 0.522 -0.917                    %6/10/97
13.472 -3.556 0.676 -0.1900 0.456 -1.324                    %18/10/97
13.426 -3.299 1.157 -0.3508 1.339 -0.056                    %2/11/97
%NaN NaN NaN NaN NaN NaN                            %no data for 17/11/97
NaN     -3.34 0.80       -0.25    0.64 -0.720       %extrapulate data for 17/11
11.648 -3.239 0.863 -0.2665 0.745 -0.755                    %25/11/97
14.191 -3.449 1.021 -0.2963 1.043 -0.483                    %2/12/97
14.452 -3.407 1.124 -0.3300 1.263 -0.268            ];      %12/12/97
%13.967 -3.558 0.770 -0.2164 0.593 -1.085                   %31/1/98
%15.463 -3.588 0.994 -0.2771 0.989 -0.4403];                        %1/4/98
```

Appendix 7

Extended Time Gravel Forms, Example Form Summary

EXTENDED TIME GRAVEL FORMS

BLADES



Lineartrends (y=mx+c)

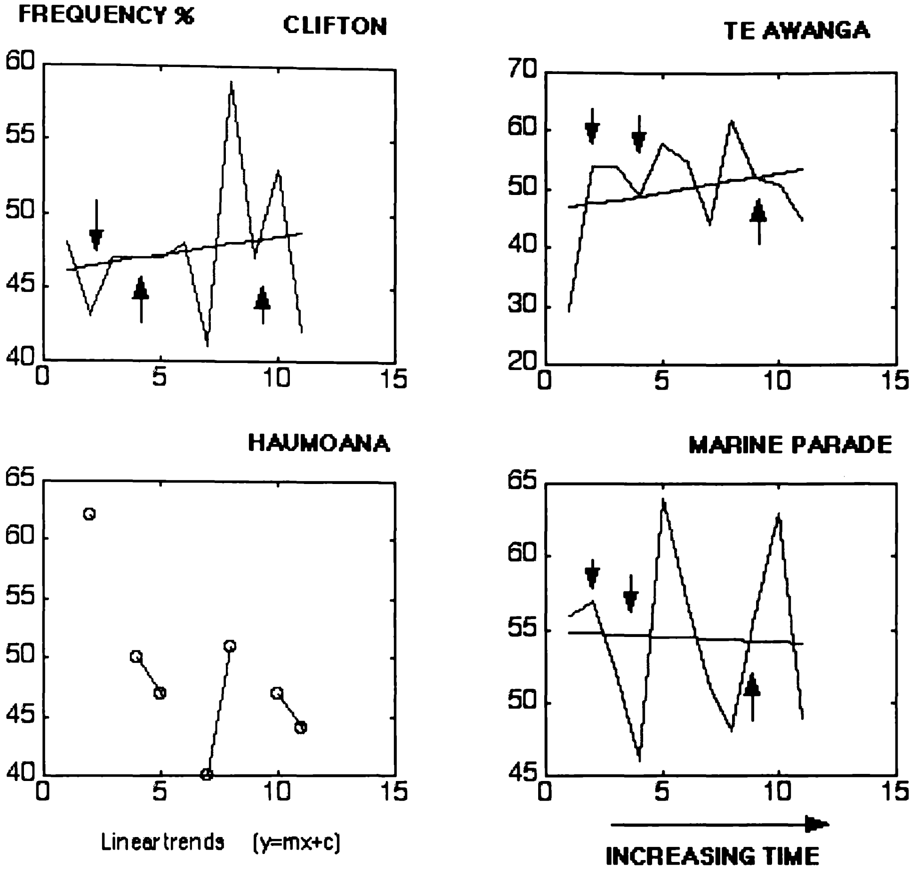
	m	c
Clifton	0.74	11.40
Te Awanga	-0.35	16.98
Haumoana	-	-
Marine Parade	-0.48	20.62

Sample Dates

20 Sept 97 27 Sept 97 *
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 * 31 January 98
25 April 98

* High energy (H_b) > 1.0 m ↓

DISCS



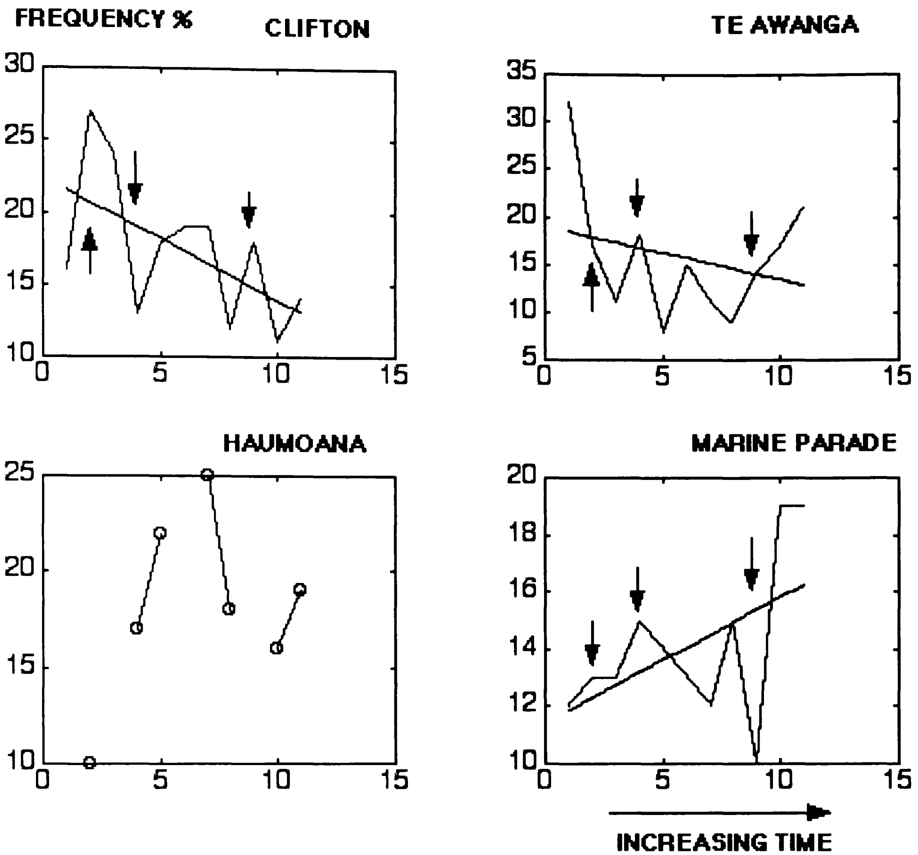
Linear trends (y=mx+c)

	m	c
Clifton	0.25	45.93
Te Awanga	0.67	46.24
Haumoana	-	-
Marine Parade	-0.07	54.89

Sample Dates
20 Sept 97 27 Sept 97 *
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 * 31 January 98
25 April 98

* High energy (H_b) > 1.0 m ↓

RODS



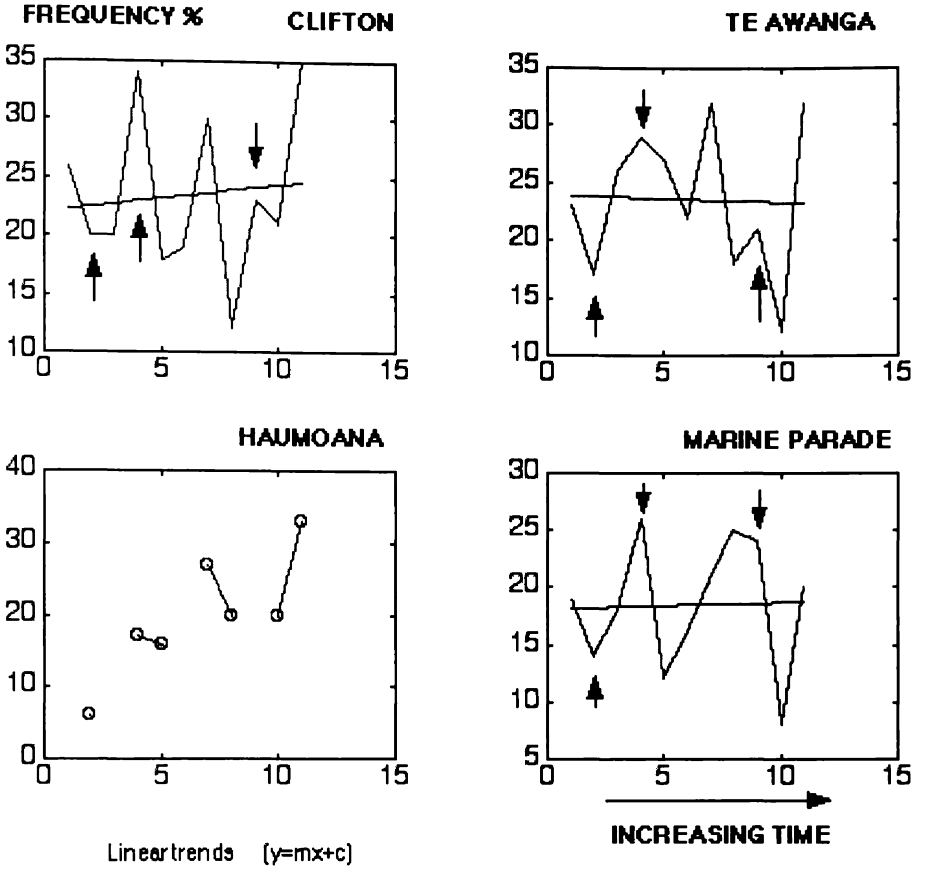
Linear trends (y=mx+c)

	m	c
Clifton	-0.84	22.44
Te Awanga	-0.55	19.05
Haumoana	-	-
Marine Parade	0.44	11.47

Sample Dates
20 Sept 97 27 Sept 97 *
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 * 31 January 98
25 April 98

* High energy (H_b) > 1.0 m ↓

SPHERES



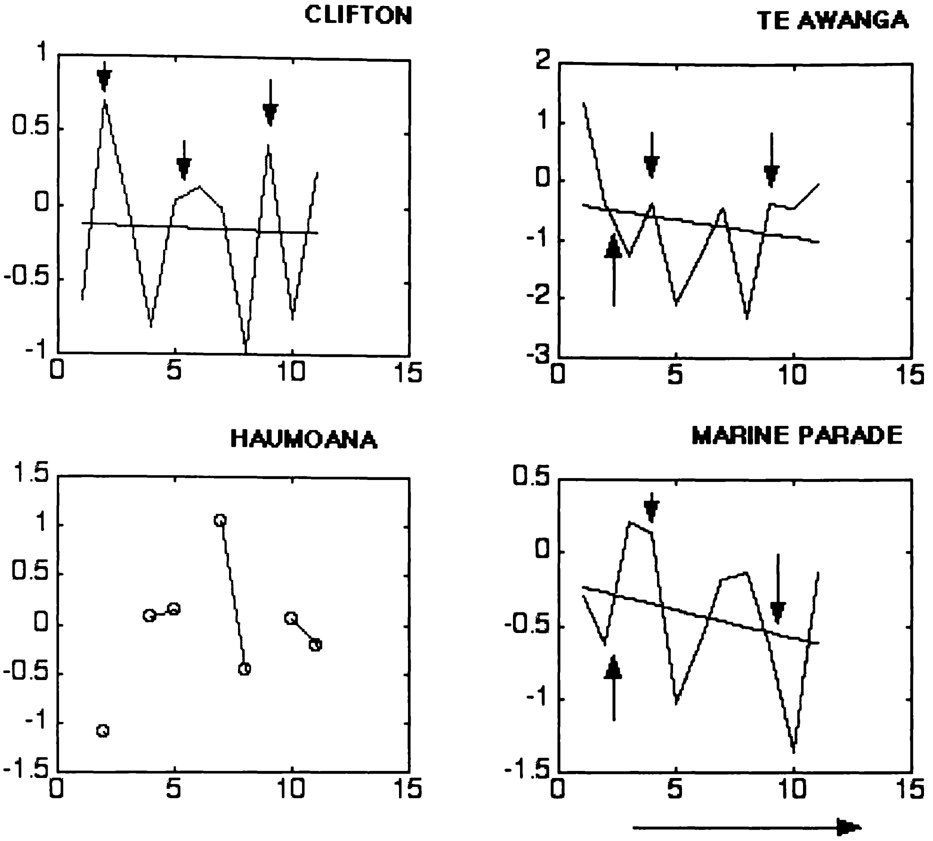
Linear trends (y=mx+c)

	m	c
Clifton	0.24	22.04
Te Awanga	-0.06	23.93
Haumoana	-	-
Marine Parade	0.05	18.13

Sample Dates
20 Sept 97 27 Sept 97 *
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 * 31 January 98
25 April 98

* High energy(H_b) > 1.0 m ↓

OBLATE PROLATE INDEX



INCREASING TIME

Linear trends (y=mx+c)

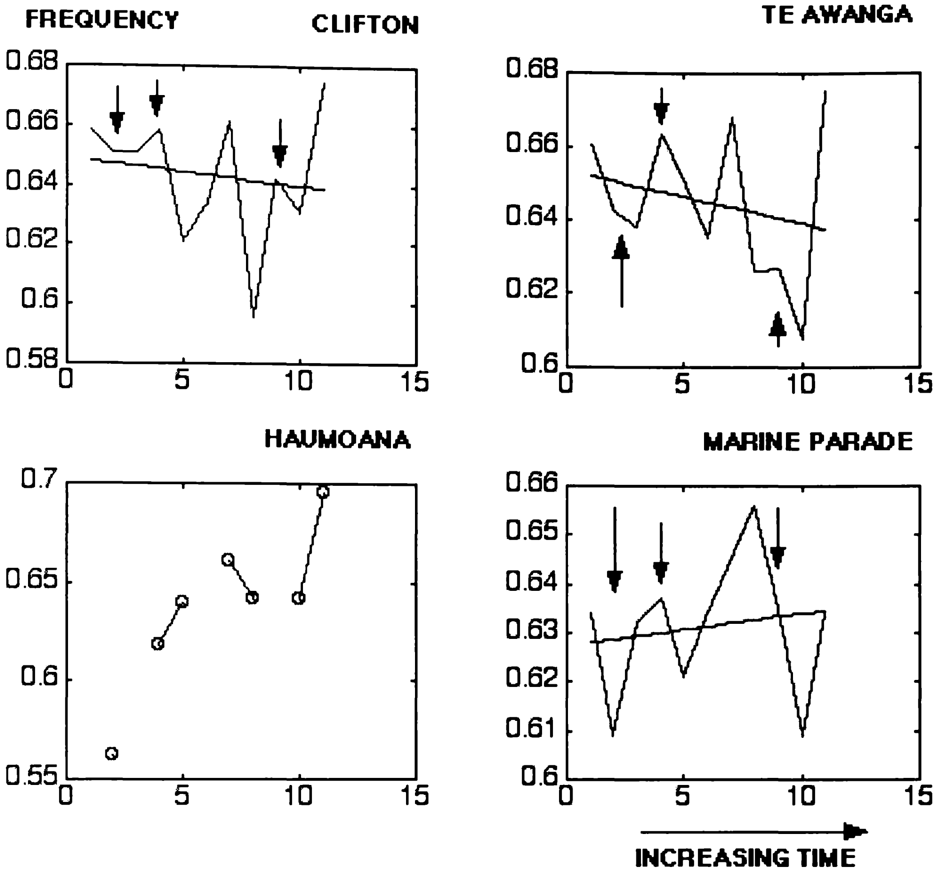
	m	c
Clifton	-0.005	-0.126
Te Awanga	-0.060	-0.346
Haumoana	-	-
Marine Parade	-0.039	-0.19

Sample Dates

20 Sept 97 27 Sept 97 *
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 * 31 January 98
25 April 98

* High energy (H_b) > 1.0 m ↓

MAXIMUM PROJECTION SPHERICITY



Linear trends (y=mx+c)

	m	c
Clifton	-0.001	0.649
Te Awanga	-0.001	0.653
Haumoana	-	-
Marine Parade	0.001	0.628

Sample Dates
20 Sept 97 27 Sept 97*
6 Oct 97 18 Oct 97 *
2 Nov 97 17 Nov 97
25 Nov 97 2 Dec 97
12 Dec 97 * 31 January 98
25 April 98

* High energy(H_b) > 1.0 m ↓

GRAVEL FORMS (ZINGG FORMS) EXAMPLE

```
%TE AWANGA
%Temporal clast form changes
%columns are from the left to right forms Blades Discs Rods Spheres
%rows are counts totals all sizes

W=[
21 29 32 23          %20/9/97 n=105 all n's unless specified
17 54 17 17          %1/10/97 surrogate 27/9 as used in size data
18 54 11 26          %6/10
9 49 18 29           %18/10
12 58 8 27           %2/11
13 55 15 22          %17/11
18 44 11 32          %25/11
6 62 9 18            %2/12
18 52 14 21  %];     %12/12

25 51 17 12          %31/1/98
7 45 21 32    ];     %25/4/98

x=1:11;

Blades=W(:,1);
Discs=W(:,2);
Rods=W(:,3);
Spheres=W(:,4);

hold on
%subplot(2,2,1),plot(x,Blades,'b')
%subplot(2,2,2),plot(x,Discs)
%subplot(2,2,3),plot(x,Rods,'g')
%subplot(2,2,4),plot(x,Spheres,'r')

n=1;
p=polyfit(x',Blades,n)
z=polyval(p,x');

p1=polyfit(x',Discs,n)
z1=polyval(p1,x');

p2=polyfit(x',Rods,n)
z2=polyval(p2,x');

p3=polyfit(x',Spheres,n)
z3=polyval(p3,x');

subplot(2,2,1),plot(x,Blades,'r',x,z,'y')
subplot(2,2,2),plot(x,Discs,'g',x,z1,'g')
subplot(2,2,3),plot(x,Rods,'c',x,z2,'c')
subplot(2,2,4),plot(x,Spheres,'m',x,z3,'m')
```

Appendix 8

Cross-shore Transverse Profile, Data and Datum

TRANSVERSE PROFILES, DATA AND DATUM

Data.

There are two imperfections with the data series covering the sample period.

1). The profiles are not continuous and three separate months were not sampled between May 1997 and June 2001.

2). The time intervals between profiling was irregular and interpolation is not used.

Spatially there are inaccuracies. These can arise from using fixed cross-shore distance points for measuring the vertical height, as the beachface slope changes so the fixed distance will swing through an arc, for example as the beach slope steepens so the sampling cross-shore distance shortens with respect to the horizontal. In high seas it was not possible to survey at the lower beachface to the set distances. Some of the data for the down beach distance extremities are by extrapolation based upon visual estimate.

At the end of Appendix 8 is an example of the time series of the transverse profile indicator parameters. These sample dates were selected for bivariate plots and time series in Chapter 7.

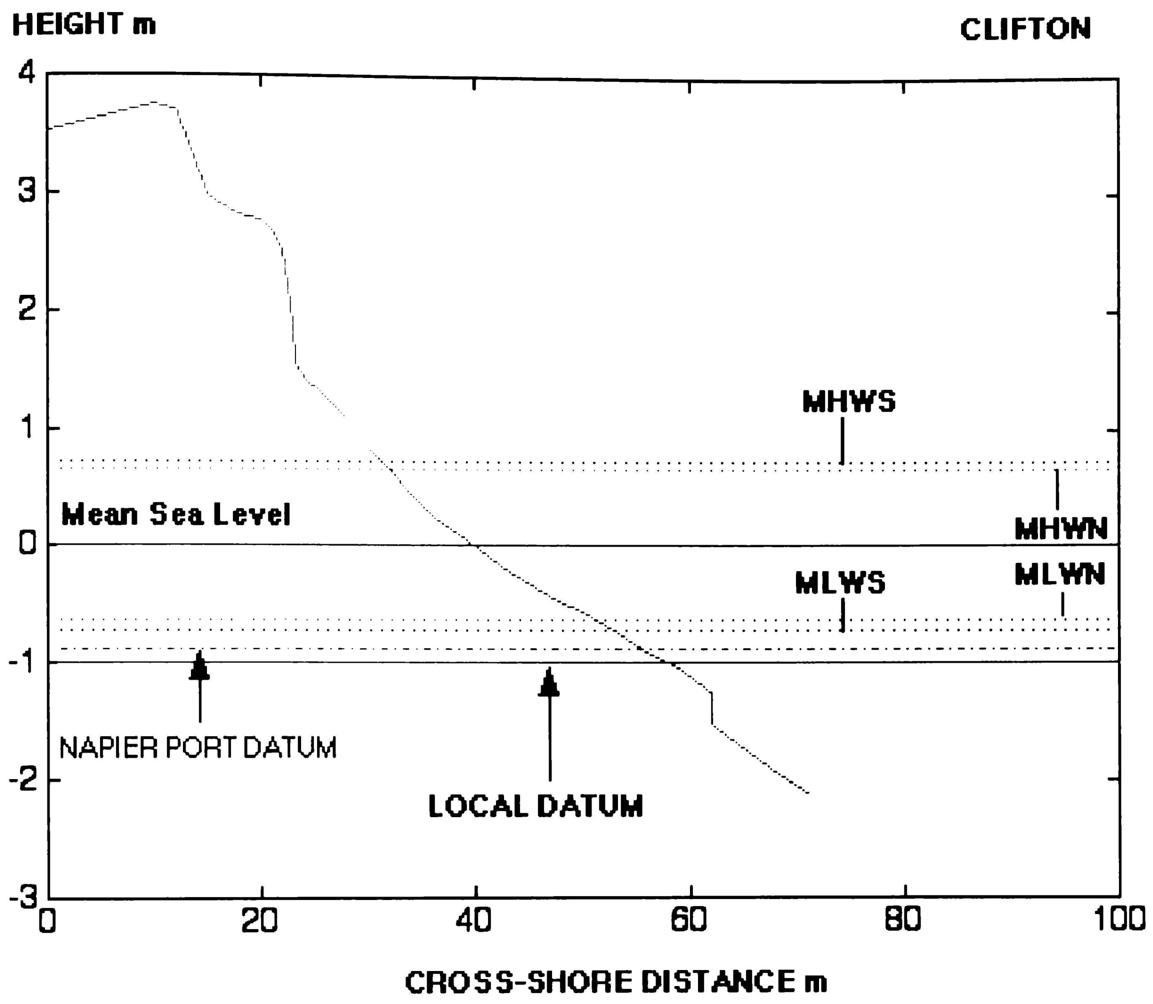
Datums.

At each site the LOCAL DATUM is used. Local Datum is a composite of three vertical heights comprising the Local HBRC Datum + Napier Port tidal station datum + bit more for errors.

(1). HBRC datum is Mean Sea Level., + (2). Napier port tidal station datum is 0.88 m below MSL. This is the lowest astronomical tide, and chart datum. + (3). Bit more to allow for errors. Last data point is made to a distance to attain the local datum. At five sites the local datum is at MSL-1.0 m, where these are Clifton, Te Awanga Hall, Te Awanga K2, Haumoana and Marine Parade.

Local Datum at Each Site.

The datum is important as it high lights the very different answers obtained by altering the local datum. This applies to the derivatives of the geometric profile indicators, the beach width and height, the derived beach volume, and profile shape index (PI). The geometry can also effect the average profile slope which if used with the wave steepness can produce differences in the ranges of the morphodynamic surf scaling parameter and the Iribarren number.



MSL	Mean Sea Level
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MHWN	Mean High Water Neaps
MLWN	Mean Low Water Neaps

Napier port datum tide levels

MSL	0.0 m
MHWS	+0.72 m Spring
MLWS	-0.72 m Spring
MHWN	+0.64 m Neaps
MLWN	-0.64 m Neaps

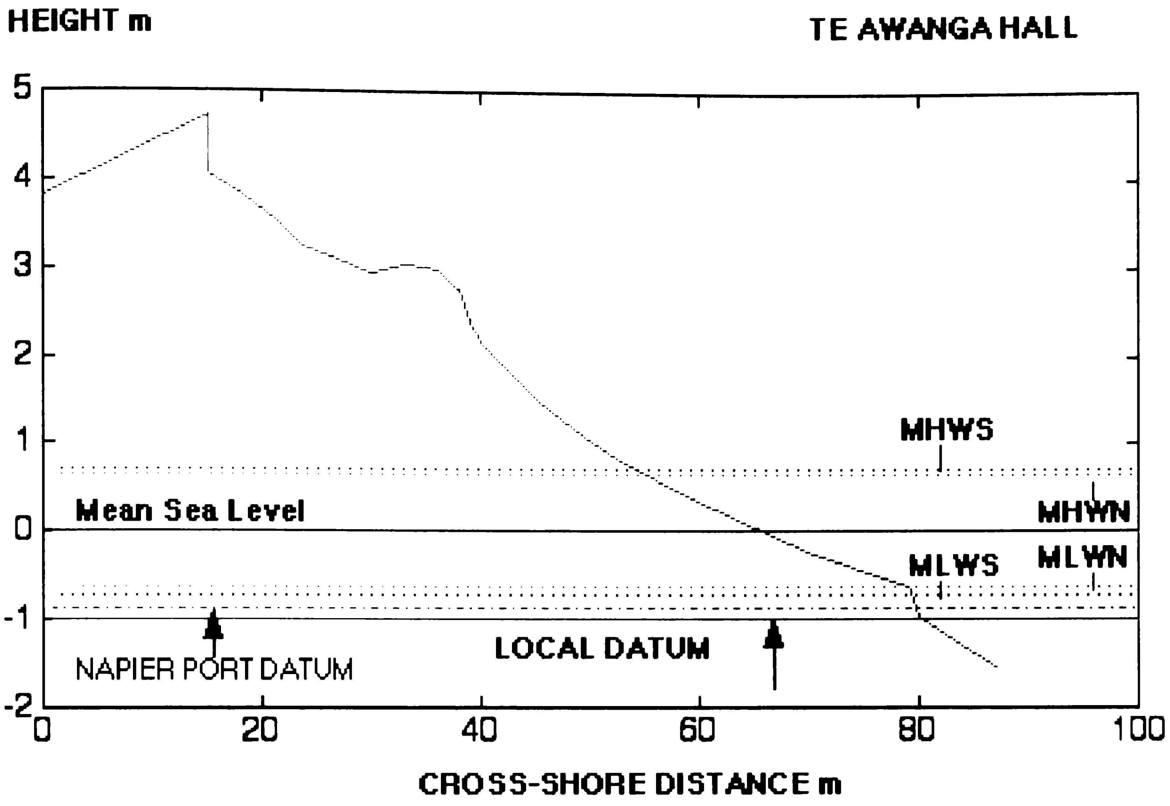
Local Datum at -1.0 m below MSL
Napier Port Datum at -0.88 m below MSL

Date 6 October 1998
survey time 1247 NZDT

Tide low water 1227	0.0 m
Springs	1.7 m

Measured in field
Low tide at 56 m
(cross-shore
distance)
Water depth at last data 1.1 m

Note the difference between the measured low tide and that predicted by Napier port tidal gauge.



MSL	Mean Sea Level
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MHWN	Mean High Water Neaps
MLWN	Mean Low Water Neaps

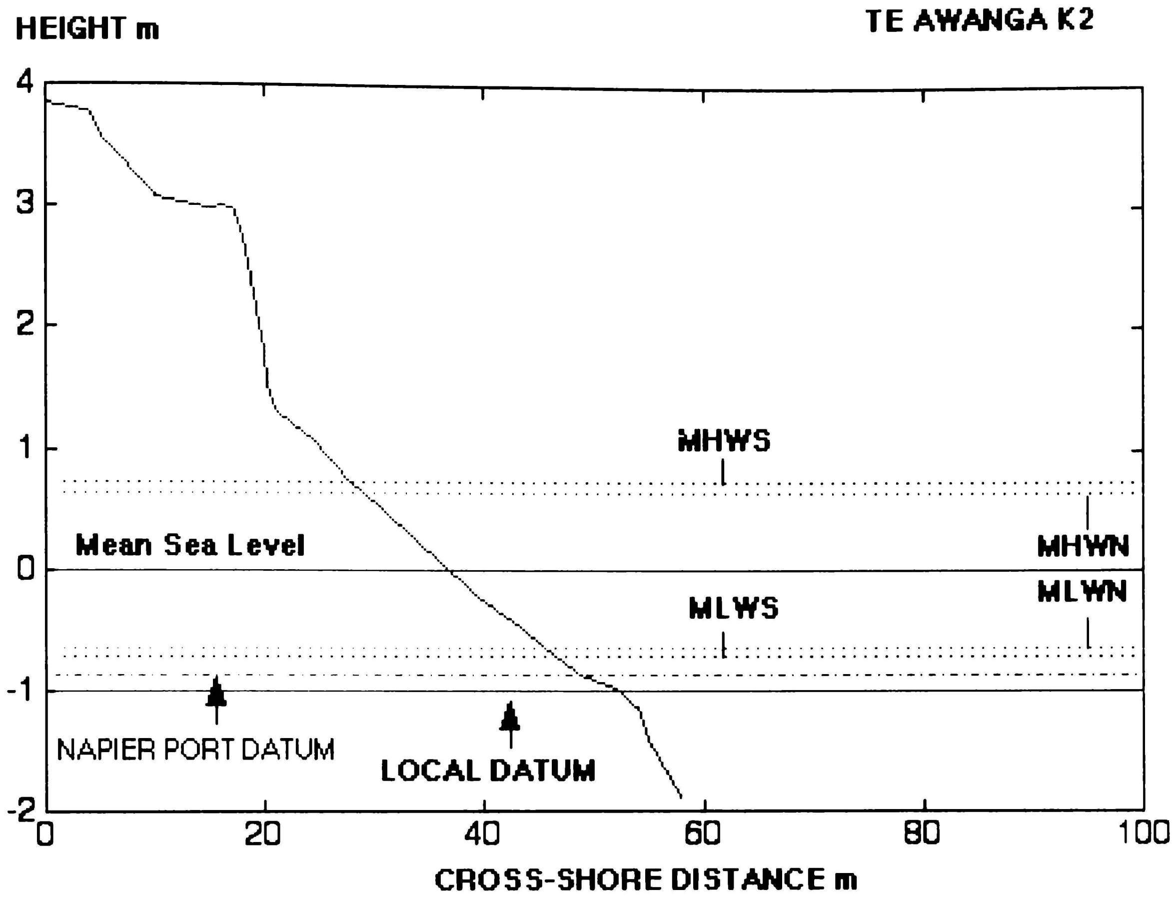
Local Datum at -1.0 m below MSL
Napier Port Datum at -0.88 m below MSL

Date 6 October 1998
survey time 1310 NZDT

Tide low water 1227 0.0 m
High tide (Springs) 1.7 m
Low tide at 70 m (cross-shore)
Water depth at last data 1.2 m

Napier port datum tide levels

MSL	0.0 m
MHWS	+0.72 m Spring
MLWS	-0.72 m Spring
MHWN	+0.64 m Neaps
MLWN	-0.64 m Neaps



MSL	Mean Sea Level
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MHWN	Mean High Water Neaps
MLWN	Mean Low Water Neaps

Local Datum	at -1.0 m below MSL
Napier Port Datum	at -0.88 m below MSL

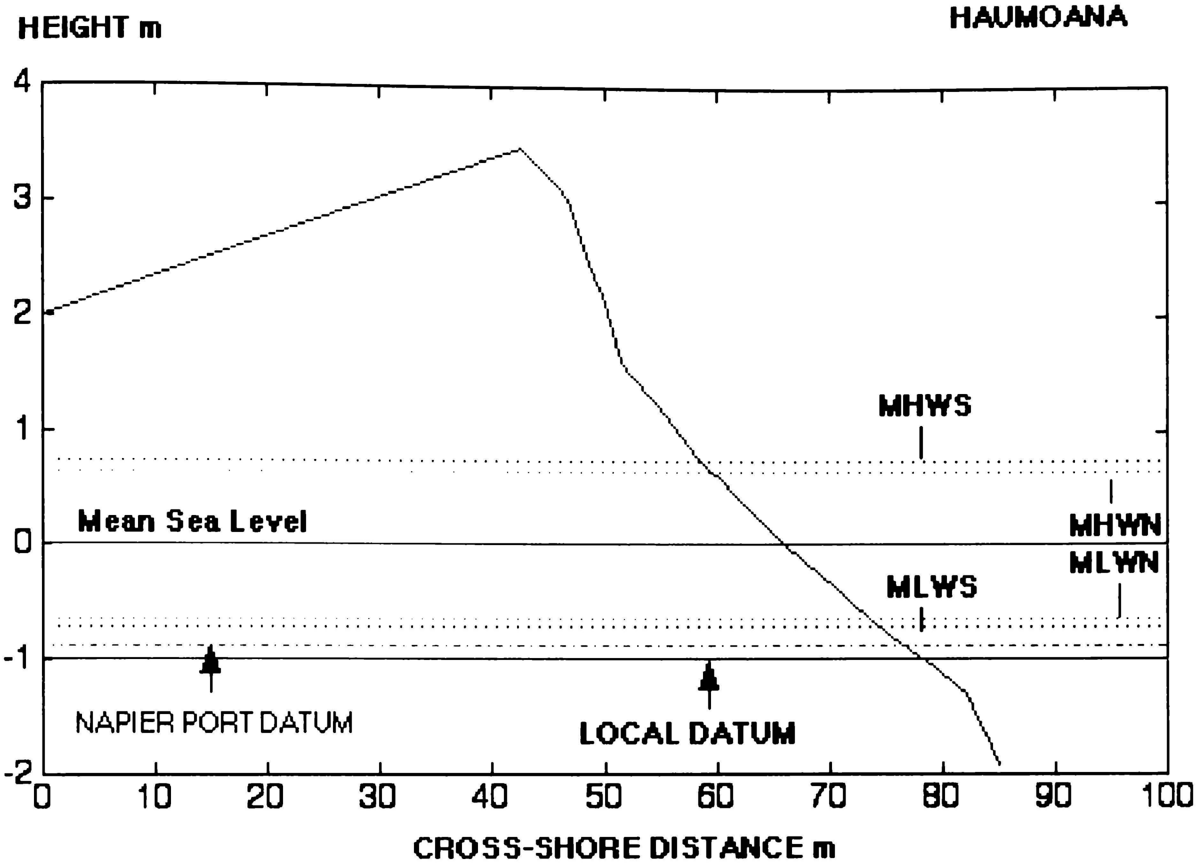
Date 6 October 1998
survey time 1340 NZDT

Tide low water 1227	0.0 m
High tide (Springs)	1.7 m

Low tide at 43 m (cross-shore)
Water depth at last data 1.0 m

Napier port datum tide levels

MSL	0.0 m
MHWS	+0.72 m Spring
MLWS	-0.72 m Spring
MHWN	+0.64 m Neaps
MLWN	-0.64 m Neaps



MSL	Mean Sea Level	Local Datum	at -1.0 m below MSL
		Napier Port Datum	at -0.88 m below MSL
MHWS	Mean High Water Spring		
MLWS	Mean Low Water Spring		
MHWN	Mean High Water Neaps		
MLWN	Mean Low Water Neaps		

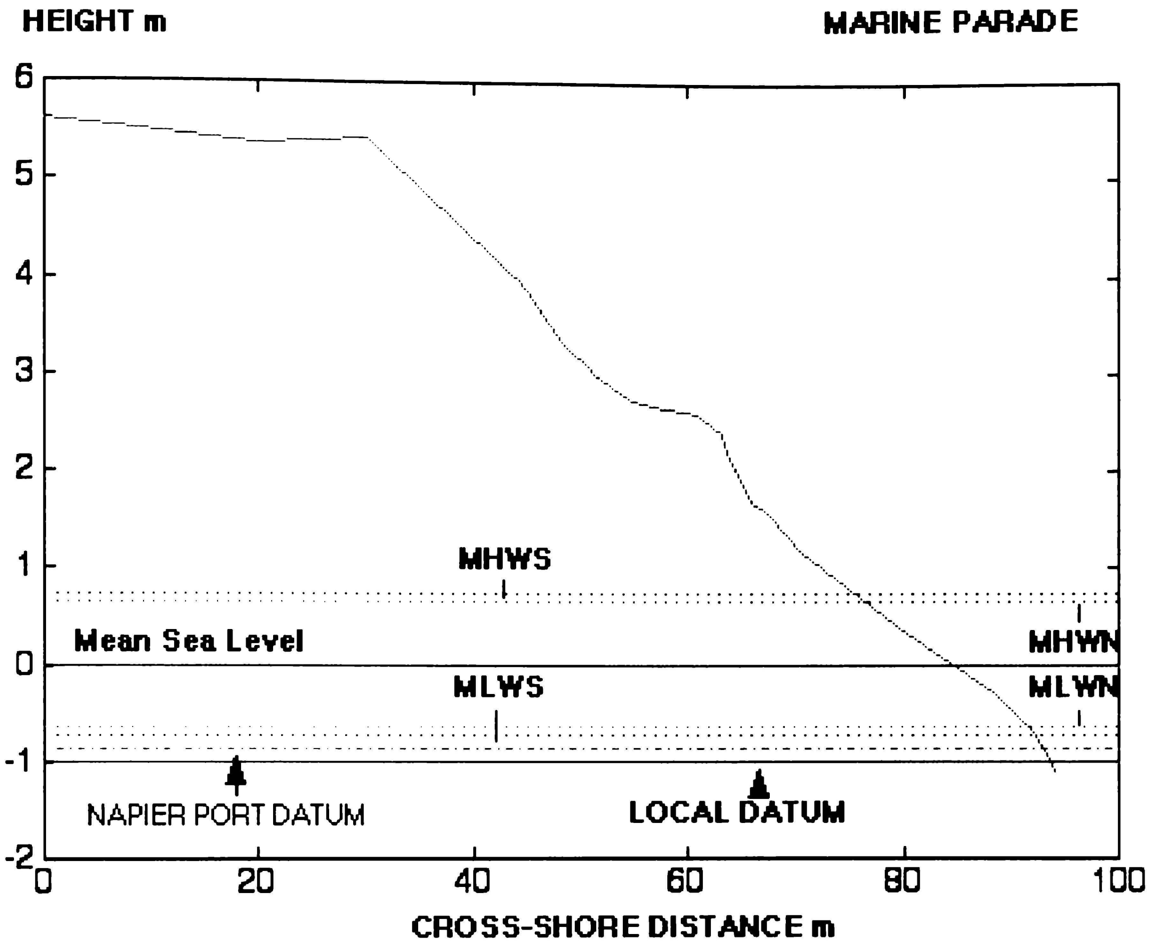
Date 6 October 1998
survey time 1412 NZDT

Napier port datum tide levels

MSL	0.0 m
MHWS	+0.72 m Spring
MLWS	-0.72 m Spring
MHWN	+0.64 m Neaps
MLWN	-0.64 m Neaps

Tide low water 1227	0.0 m
High tide (Springs)	1.7 m

Low tide at 73 m (cross-shore)
Water depth at last data NA m



MSL	Mean Sea Level
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MHWN	Mean High Water Neaps
MLWN	Mean Low Water Neaps

Napier port datum tide levels

MSL	0.0 m
MHWS	+0.72 m Spring
MLWS	-0.72 m Spring
MHWN	+0.64 m Neaps
MLWN	-0.64 m Neaps

Local Datum	at -1.0 m below MSL
Napier Port Datum	at -0.88 m below MSL

Date 16 December 1999
survey time 1910 NZDT

Tide low water 1853 0.3 m
High tide (Neaps) 1.6 m
Low tide at 88 m (cross-shore)
Water depth at last data 0.5 m

Example of Profile Data Selection.

Data with symbol '%' against left margin were not selected for the transverse profile geometric indicator analysis. This example is for Clifton.

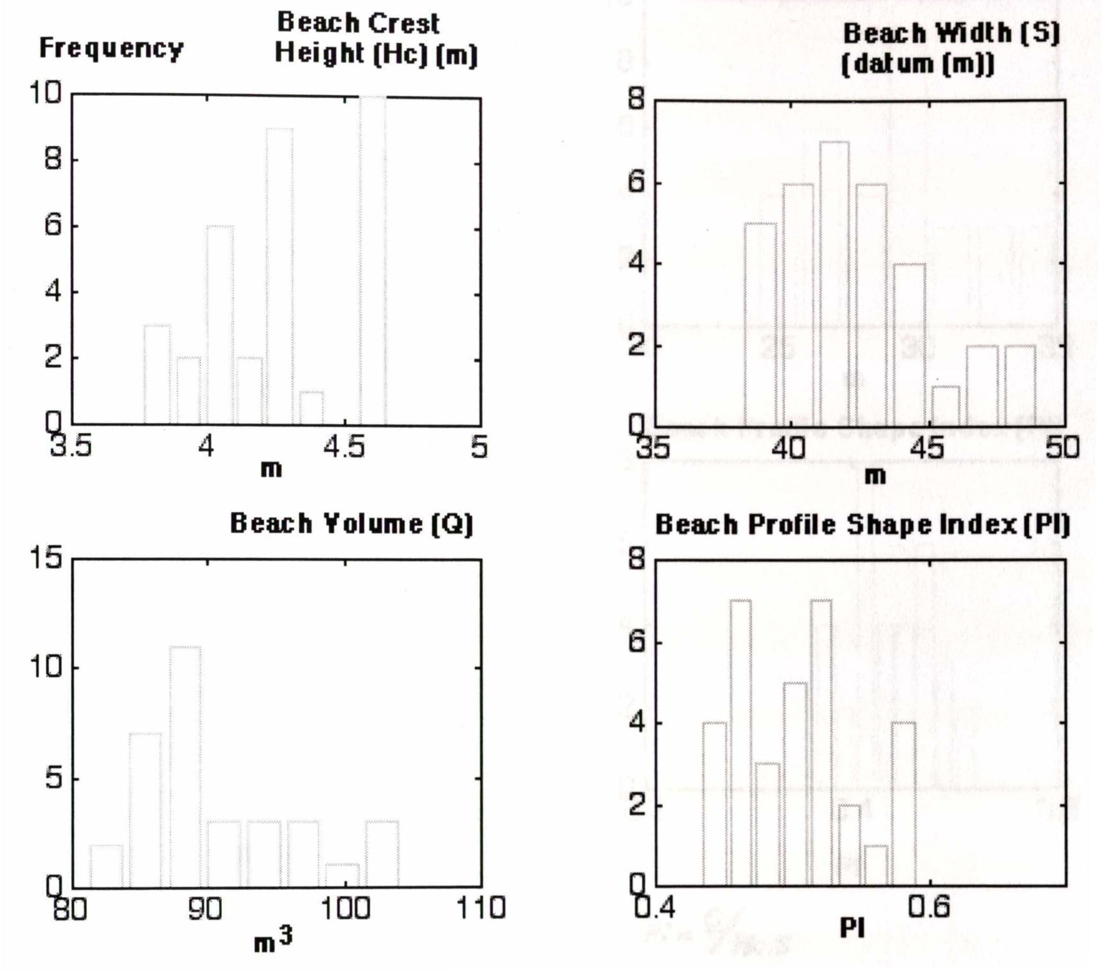
```
%CLIFTON      %LOCAL DATUM 4.5 m          SEASONAL THREE YEARS
%LOCAL DATUM 4.5m that's 3.513 HBRC + 0.88 port +0.11 for luck
%data columns are from left to right Hc crest height;S beach width to LOCAL DATUM
%and Vol sediment volume as a wedge and volume change
%crest height is at cross shore distance 10m from BM


C=[
%0.12 54 127.64                 %27May 1998
0.13 54 127.64  1               %28Jun98
0.20 46.8 126.6 -1.04           %15Jul98
0.25 51.3 135.15 8.55           %29Aug98
0.24 58.6 135.85 0.70           %6Oct98
0.23 58.8 134.77 -1.08          %14Nov98
0.2 58.1 138.72 3.95            %13Dec98
                                                    %n=7

0.17 52.4 138.87 0.15           %4Jan99
%0.2 53.3 141.32                %2Feb99             2.45
0.23 51.6 137.81 -1.06          %28Feb99      %vol diff to previous -3.51
%0.22 50.1 141.47               %16Mar99
0.23 53.2 138.64 0.83           %29Mar99
%0.23 51.1 139.93               %15Apr99
0.18 48 134.41 -4.23            %27Apr99
%0.19 48.7 137.94               %13May99
0.2 53.4 137.38 2.97            %28May99
0.15 54.3 138.13 0.75           %14Jun99
0.18 50.3 137.59 -0.54          %26Aug99
%0.25 49.5 134.14               %10Sep99
%0.27 52 133.34                 %13Sept99
0.21 54 135.76 -1.83            %24Sep99
%0.25 54.1 129.67               %7Oct99
%0.25 53.4 129.18               %8Oct99
%0.25 55.1 132.79               %18Oct99
%0.25 54.9 132.59               %19Oct99
0.22 53.8 130.01 -5.75          %29Oct99
%0.25 54 131.9                  %18Nov99
0.22 54 130.68 0.67             %27Nov99
%0.22 53.6 130.72               %2Dec99
%0.22 54.5 130.62               %3Dec99
0.24 57.5 131.82 1.14           %17Dec99
                                              %n=24
```

Appendix 9

Beachface Indicators (Histograms)

APPENDIX 9
Beachface Indicators

TE AWANGA HALL



n=33

$PI = {}^{Q}/_{Hc.S}$

where

PI = Profile shape Index

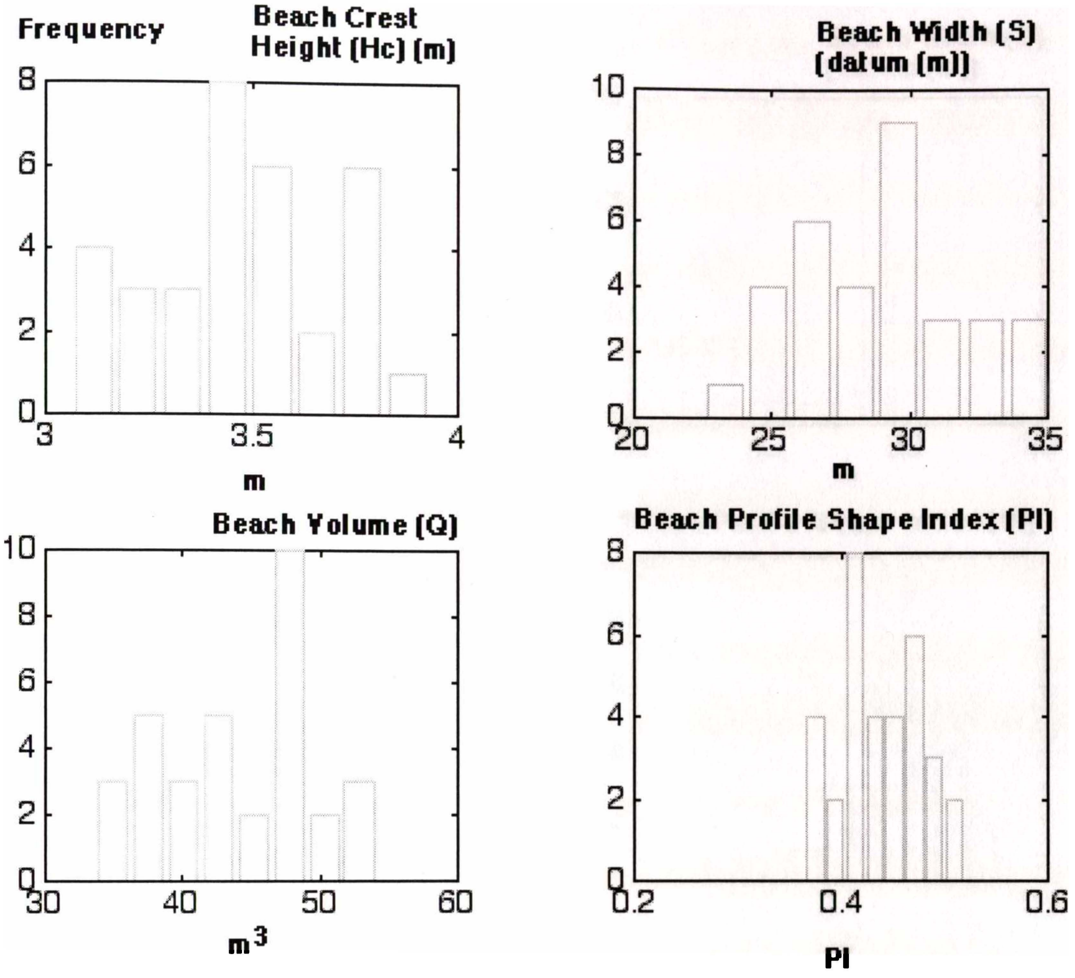
Q = sediment Volume

Hc = beachface crest Height

S = beachface width

This Appendix shows the histograms for the beachface parameters, HW ridge height (m), cross-shore width (m), sediment volume (m^3) and Profile Index. Total data is from June 1998 to May 2001, n-33 (months).

TE AWANGA K2



n=33

$$PI = \frac{Q}{Hc.S}$$

where

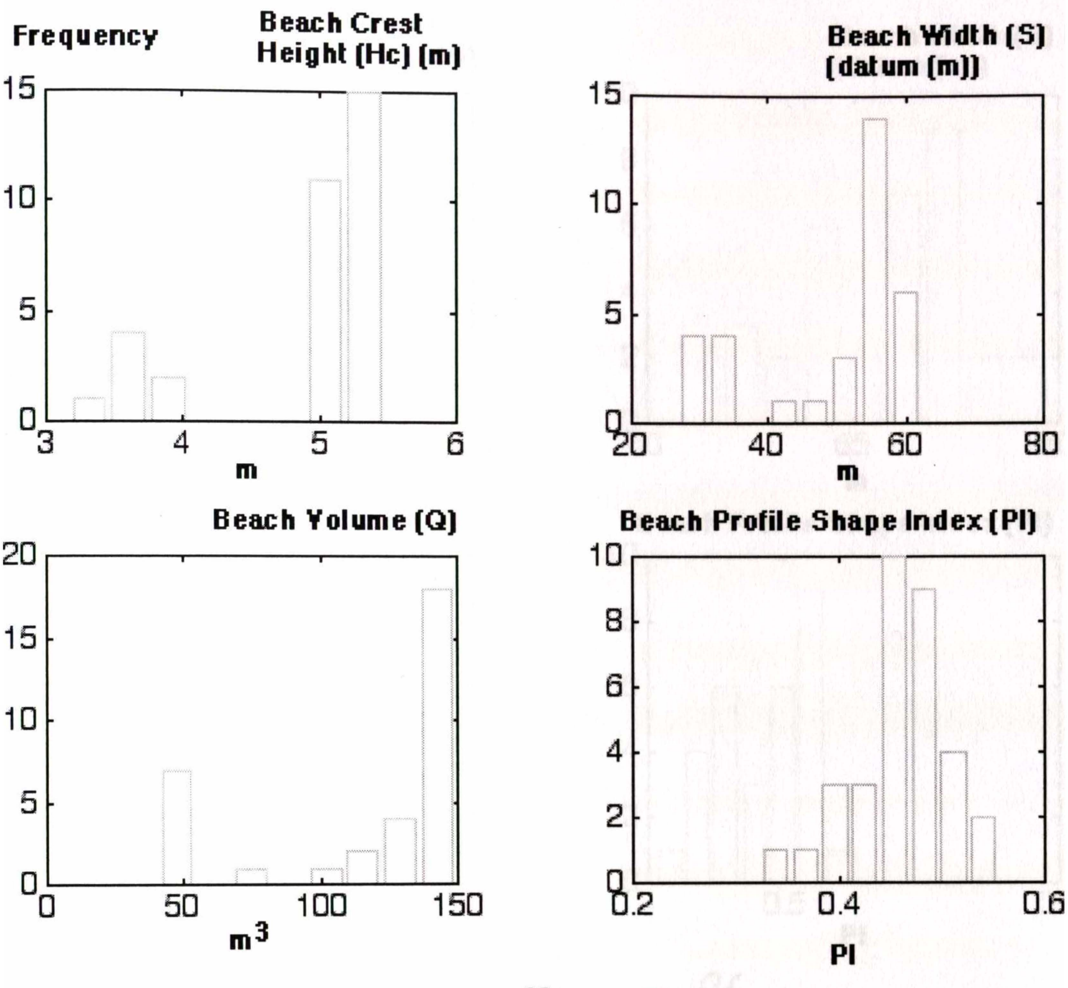
PI = Profile shape Index

Q = sediment Volume

Hc = beachface crest Height

S = beachface width

HAUMOANA



n=33

$$PI = \frac{Q}{Hc.S}$$

where

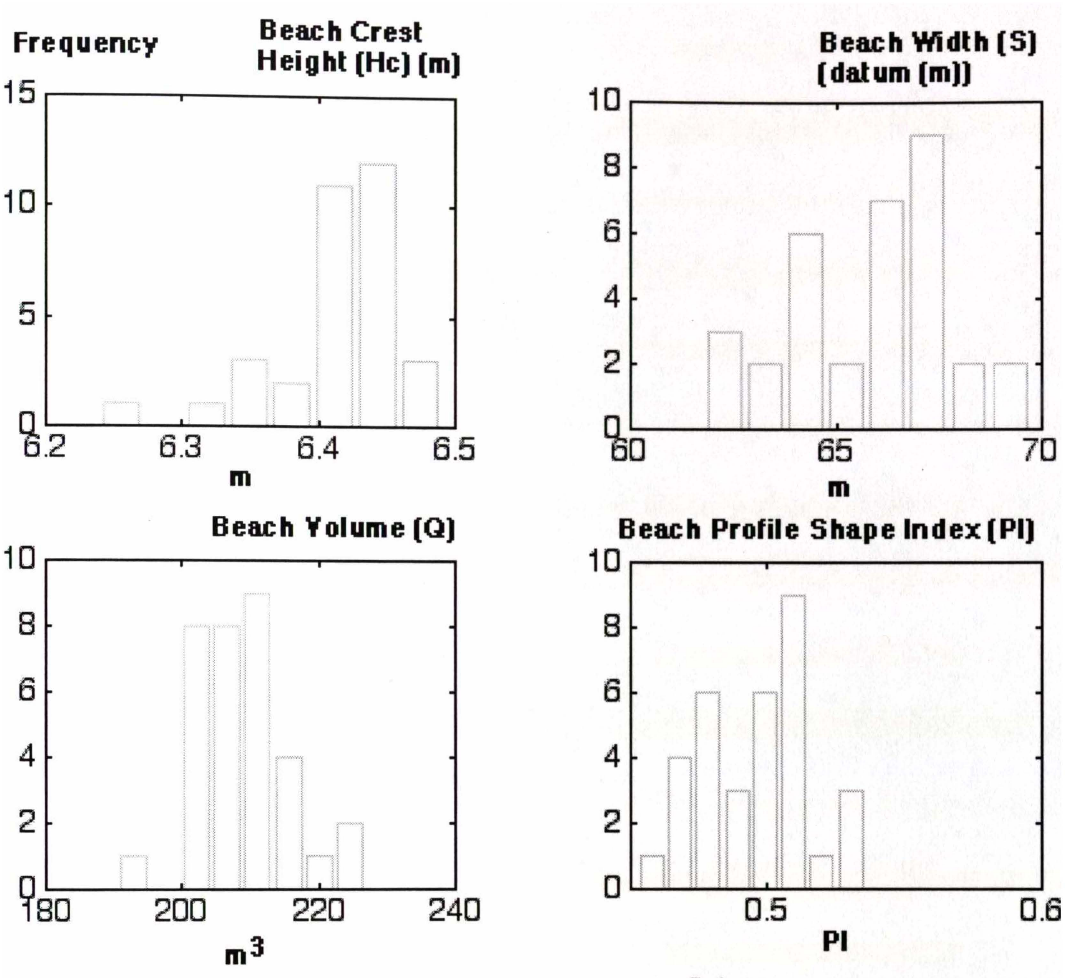
PI = Profile shape Index

Q = sediment Volume

Hc = beachface crest Height

S = beachface width

MARINE PARADE



n=33

$PI = Q/_{Hc.S}$

where

PI = Profile shape Index

Q = sediment Volume

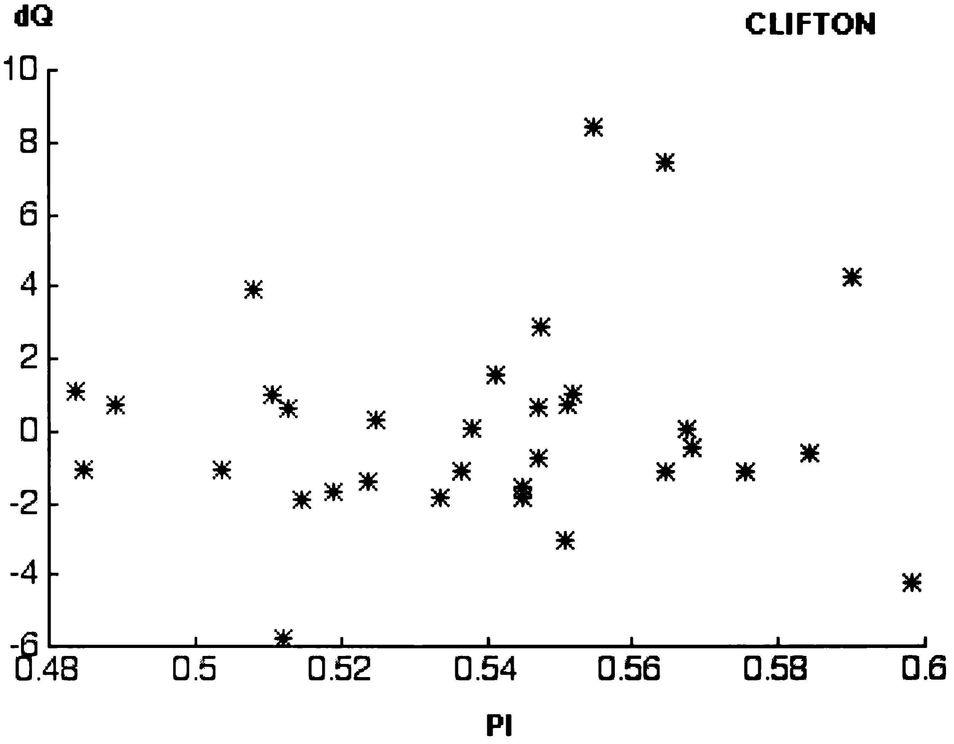
Hc = beachface crest Height

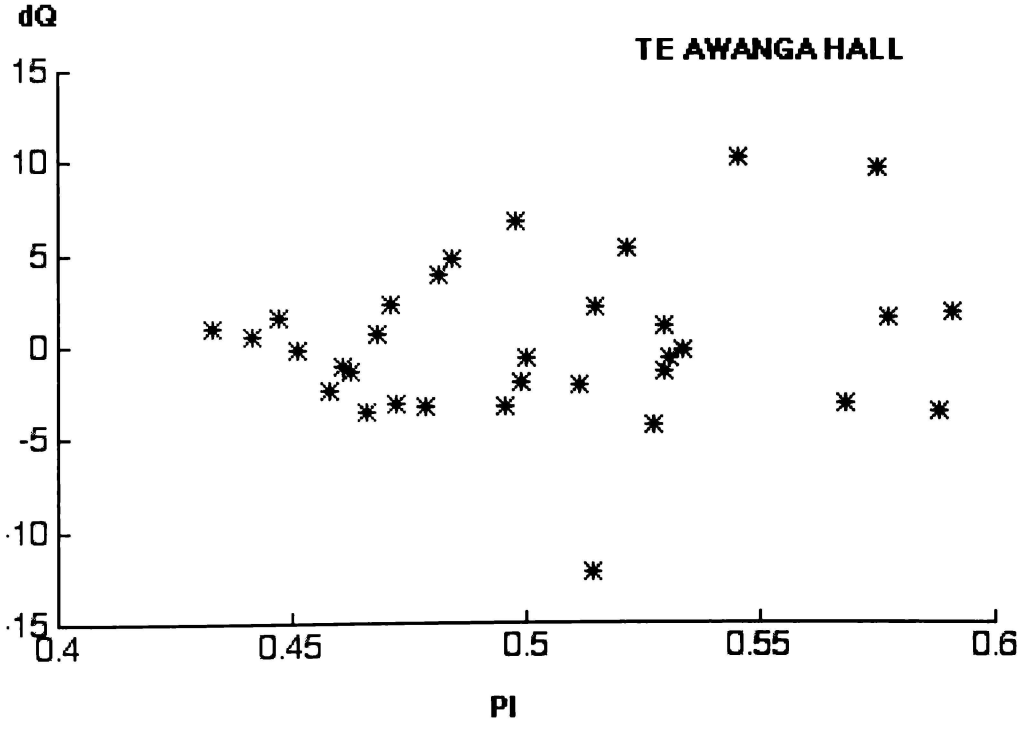
S = beachface width

Appendix 10

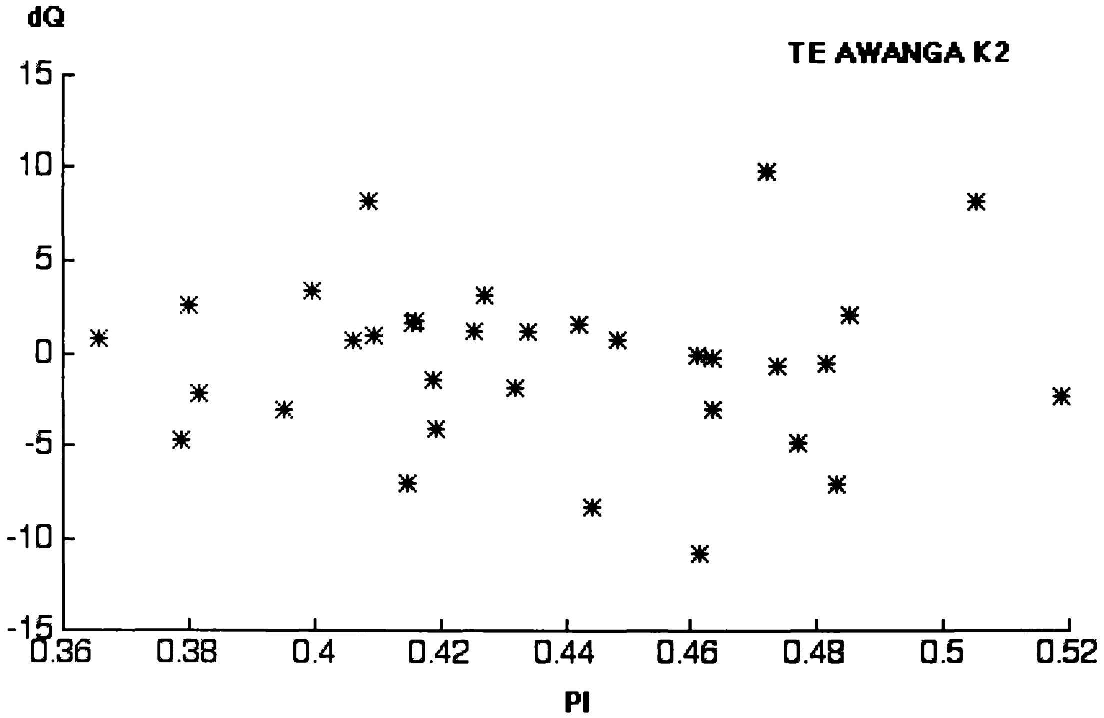
Bivariate Plots of Sediment Volume Change and the Profile Index

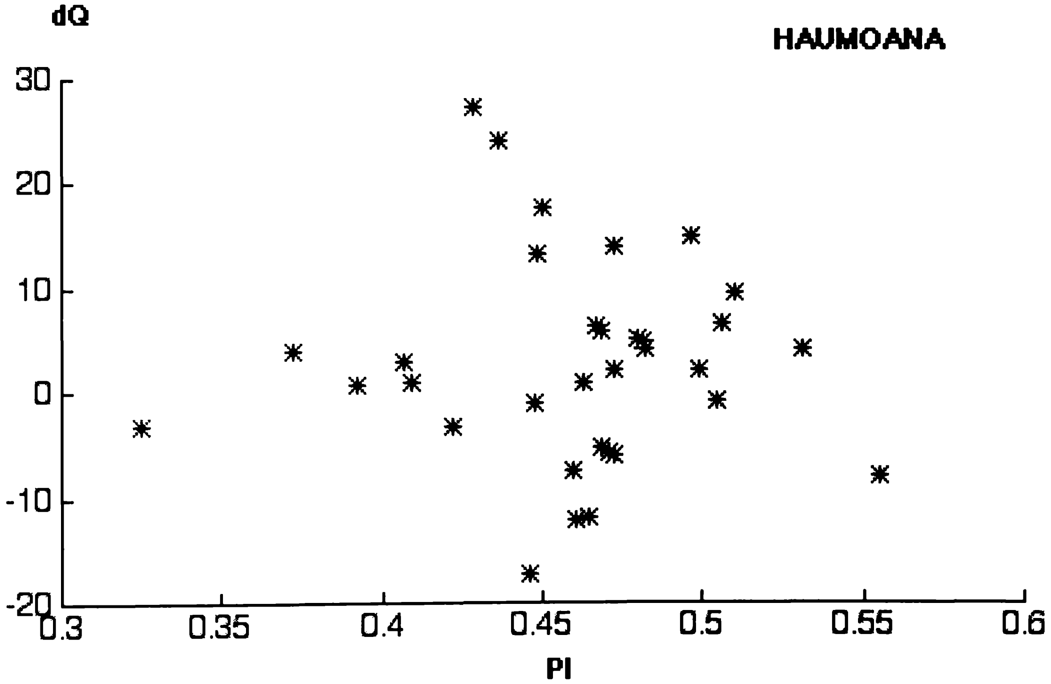
Bivariate Plots of Sediment Volume m^3 (dQ) Change and the Profile Index (PI).





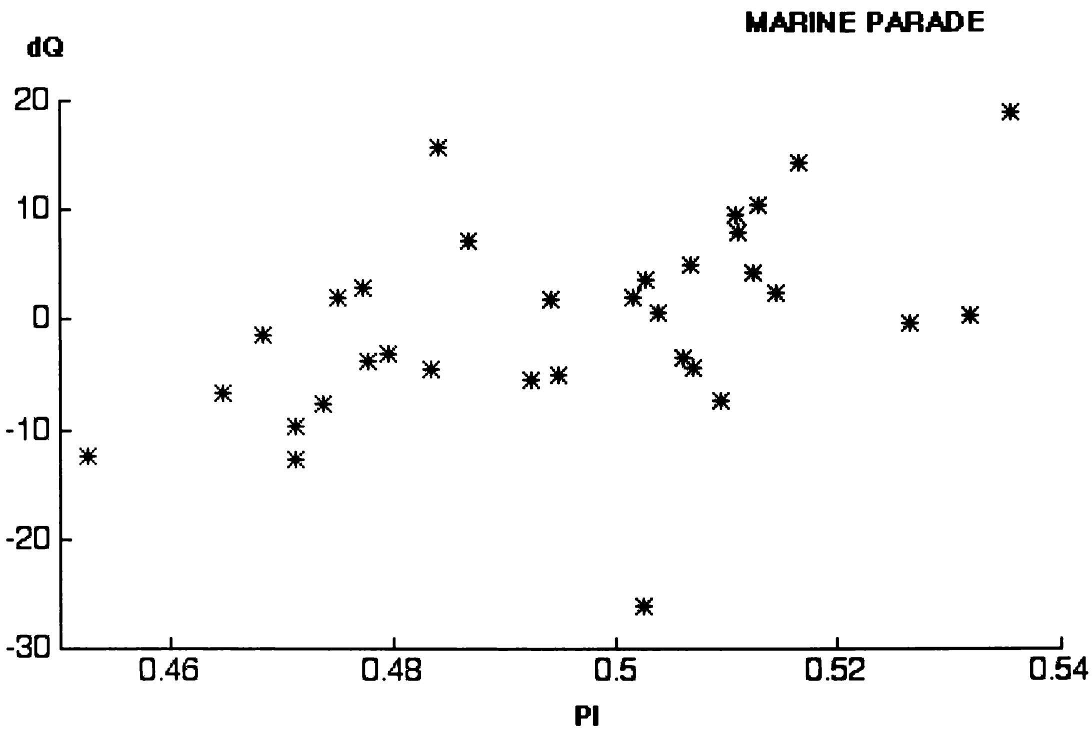
dQ	Active beachface intersample volume change (m^3)
PI	Profile Index





dQ Active beachface intersample volume change (m^3)

PI Profile Index

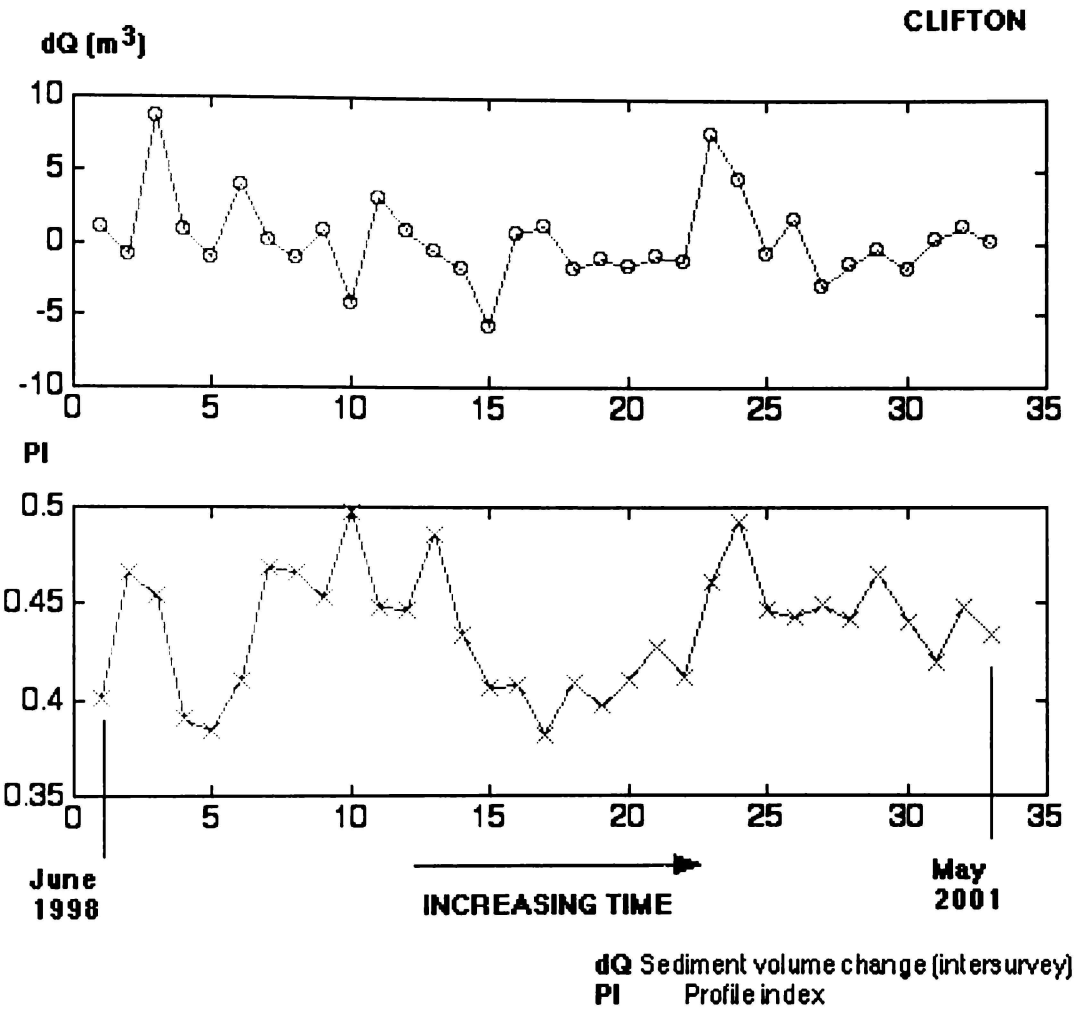

MARINE PARADE
dQ
20
10
0
-10
-20
-30
0.46
0.48
0.5
0.52
0.54
PI

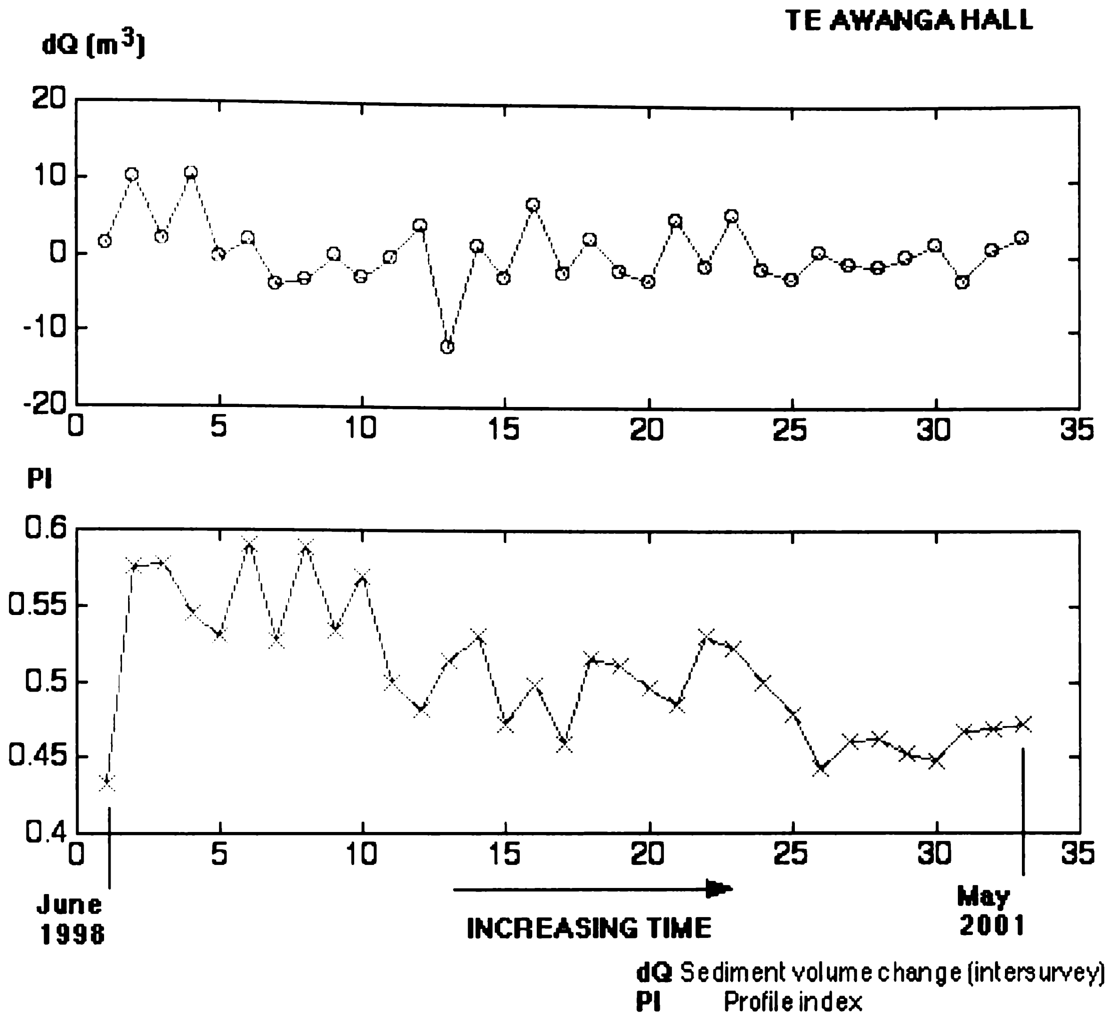
Appendix 11

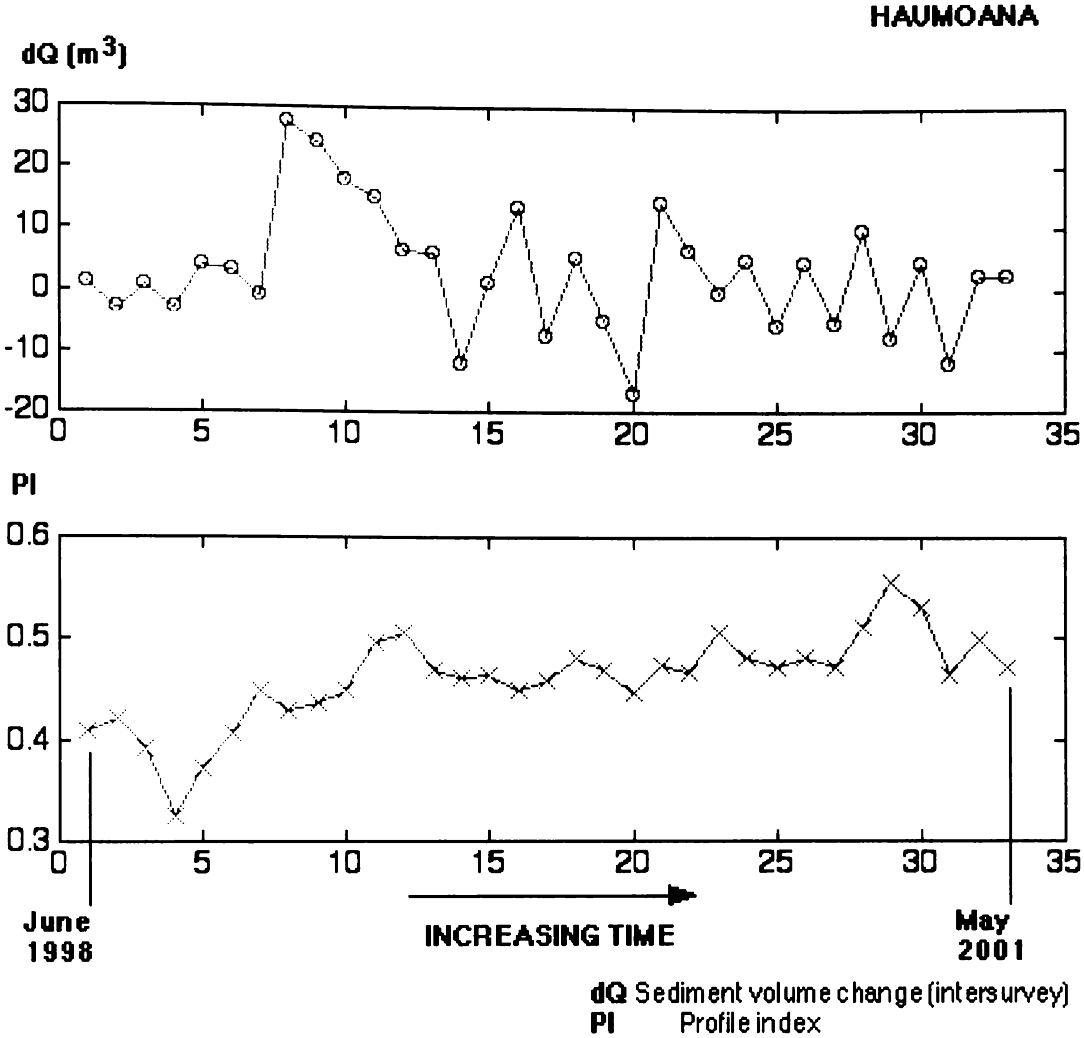
Sediment Volume Change and Profile Index Time Series

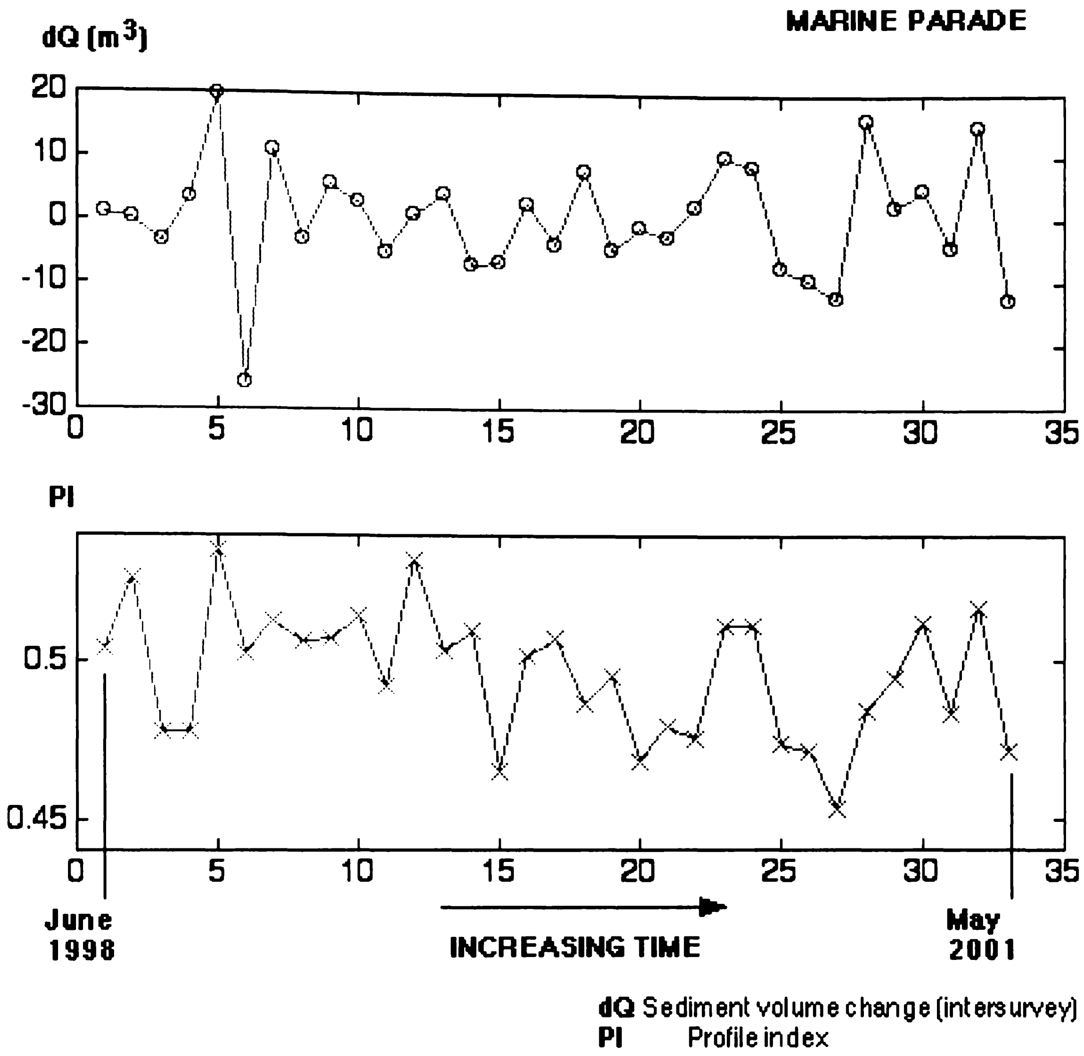
APPENDIX 11

Sediment Volume Change (m^3) and Profile Index Time Series, Southern Hawke Bay Sample Sites.




TE AWANGA HALL
dQ (m^3)
20
10
0
-10
-20
0
5
10
15
20
25
30
35
PI
0.6
0.55
0.5
0.45
0.4
0
5
10
15
20
25
30
35
June
1998
INCREASING TIME
May
2001
dQ Sediment volume change (intersurvey)
PI Profile index

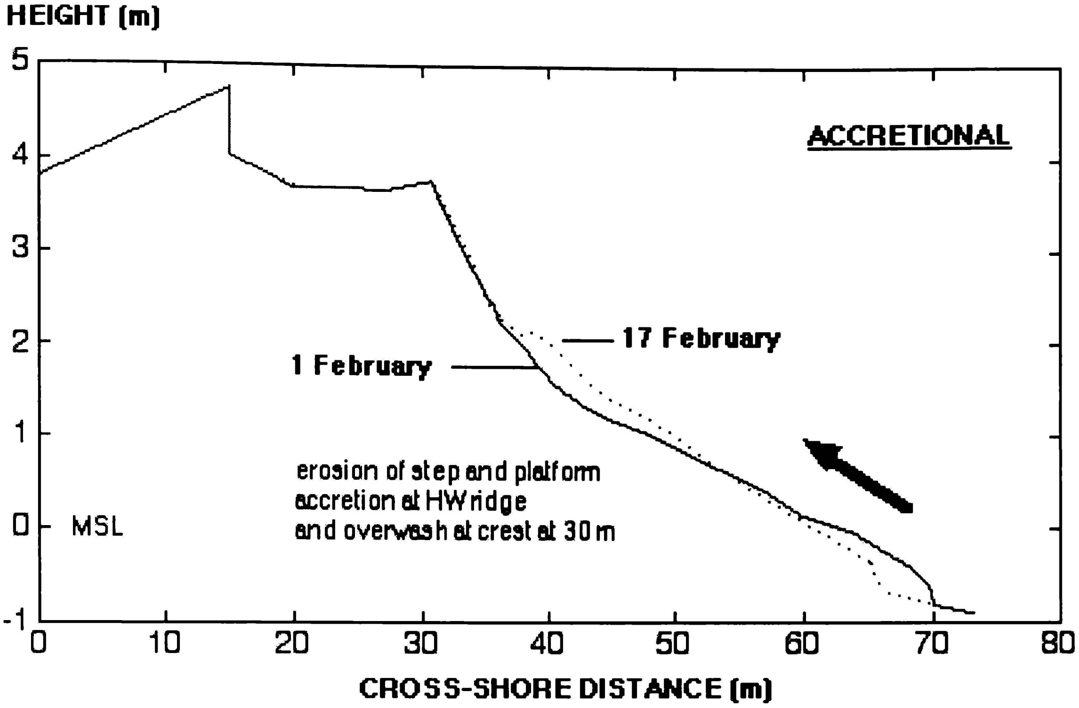

HAUMOANA
dQ (m3)
30
20
10
0
-10
-20
0
5
10
15
20
25
30
35
PI
0.6
0.5
0.4
0.3
0
5
10
15
20
25
30
35
June 1998
INCREASING TIME
May 2001
dQ Sediment volume change (intersurvey)
PI Profile index

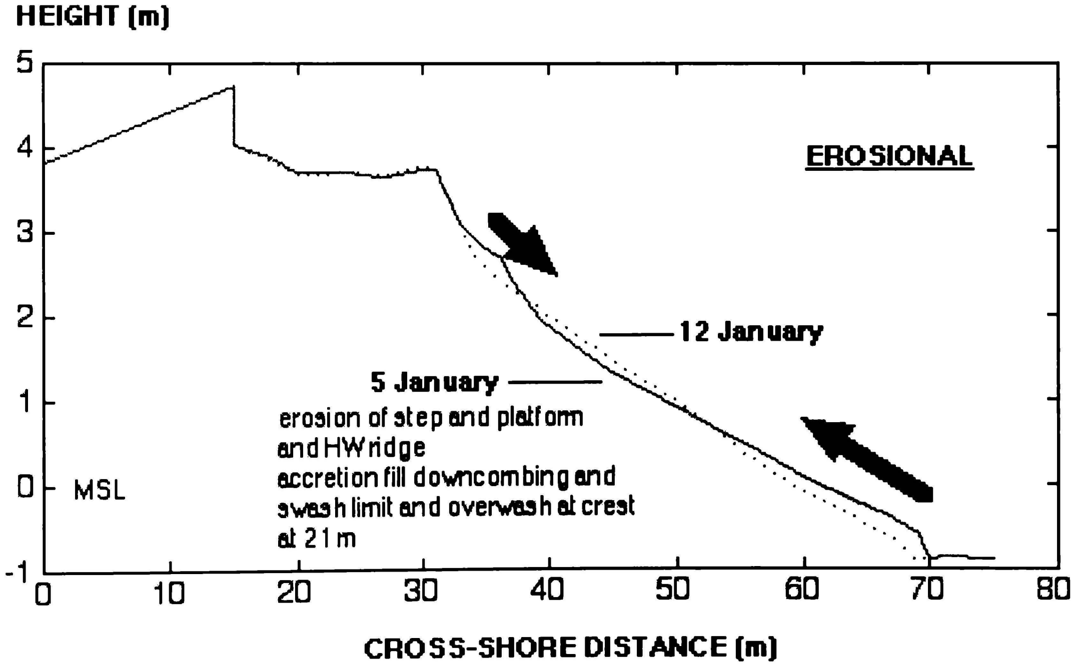

MARINE PARADE
dQ (m^3)
20
10
0
-10
-20
-30
0
5
10
15
20
25
30
35
PI
0.5
0.45
June 1998
INCREASING TIME
May 2001
dQ Sediment volume change (intersurvey)
PI Profile index

Appendix 12

Accretion and Erosion Profiles

APPENDIX 12 Accretional and Erosional Profiles





Profile lines as a time series
T1 is solid line
T2 is dotted line

↖ Direction of sediment transport

Both profile sets are characterised by increased wave steepness (B_s), and a shift from dissipative to linear profile index (PI).

Accretion has +ve sediment volume change m^3 (dQ)

Erosion has -ve (m^3) dQ