Development of the Miranda-Kaiaua Chenier Plain, Firth of Thames, New Zealand and implications for coastal hazard management

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Development of the Miranda-Kaiaua Chenier Plain, Firth of Thames, New Zealand and Implications for Coastal Hazard Management

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SUMMARY

This paper examines the hypothesis that chenier ridges between Kaiaua and Miranda may provide much useful desi information on the hazard risk posed by coastal inundation. The ridges have been dated and display distinct variations chenier width and height with age. These changes have been attributed to a ~1m drop of mean sea level during the last 36 years. However modern coastal dynamics, sediment composition of the ridges, and historic storm surge all suggest that chenier ridge elevations are primarily determined by wave action and elevated water levels. Numerical simulations of sto surges and wave propagation in the Firth are being undertaken to further develop understanding of the relationship betwe wave action and elevated water levels and chenier ridge formation and development.

INTRODUCTION

The Firth of Thames is a semi-enclosed bay (Healy and Harada, 1991) that occupies the southern Hauraki Gulf in the North Island of New Zealand (Figure 1). Surrounding the Firth are the Hunua ranges to the West, the Coromandal Peninsula to the East and the low-lying Hauraki Plains to the South. These geological features embody the northern extent of the Hauraki Depression (Hochstein and Nixon, 1979). The Kaiaua-Miranda coastline is situated along the western boundary seaward of the Hunua ranges

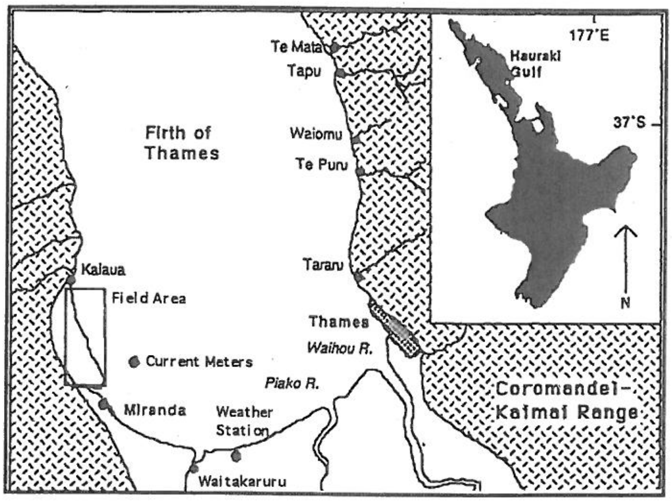

Figure 1 Map of North Island, New Zealand and the Firth of Thames showing field area and instrument positions (From Naish 1990)

This stretch of coastline consists of a Chenier Plain that has been prograding since the Holocene marine transgression (Schofield, 1960, Woodroofe, Curtis and McLean, 1983). The morphology of Chenier ridges was thought to have been indicative of an overall sea level fall from a high of 2.1m above present levels (Schofield 1960). However investigation into the elevation of the bi-valve *Mactra* at the base of Chenier ridges (Woodroffe, Curtis and McLean 1983), implied that a sea level 0.70 - 0.90m above prese existed 3600 years ago. The sealevel then reced gradually until close to the present level, 1200 years ago.

The Kaiaua - Miranda area has a history of sea inundati due to storm surge. The contributing factors include low-lying topography, the physical form of the Firth Thames and the lack of coastal protection. Although Hauraki Plains is also low lying, construction of flo protection works (such as stop banks and floodgates) prevented major inundation or flooding to date.

Storm surge effects in the Firth of Thames are intensifi when northerly winds (which induces greater wave set and run up due to larger fetch) combine with low pressure and high tide to increase local sea elevati High rainfall also exacerbates flooding, but storm sur effects are still significant without substantial rainfall.

Coastal erosion is encroaching on the East Coast ro which runs along the Kaiaua-Miranda coastline. Howev adequate coastal protection schemes cannot be develop until there is more knowledge concerning historical sto events and erosion trends.

AIMS

The aim of this study is to produce a historical record storm surge along the Kaiaua – Miranda coastline duri the Holocene period. This will transcend towa improved coastal management of the coastline. In process of carrying out the above aim, the followi objectives are necessary.

- To numerically model storm surge conditions alo the Kaiaua-Miranda coastline
- To correlate chenier dimensions with storm sur conditions using a numerical model.
- To determine coastal hazard risk from histori chenier ridges using a numerical model.

- To determine coastal erosion/accretion trends along the Kaiaua - Miranda coastline.
- To investigate possible coastal protection measures for the Kaiaua - Miranda coastline.

DATA COLLECTION

A weather station was installed on December 9, 1996, attached to a disused radio repeater mast, approximately 10m above MSL. The weather station is situated approximately 800m from the southern coastline of the Firth of Thames at Waitakaruru, southeast from the field area (Figure 1). The telemetry is set to record wind speed and direction (vector averaged every 15min) and air pressure (recorded every 15min). Due to the surrounding topography, nearby weather stations were deemed inadequate to correlate wind climate with wave climate for this particular area.

There have been no previous measurements of hydrodynamics along this coast, therefore investigations into the wave and current climate was required. S4adw and S4dw current meters were used to record wave height and direction and current speed and direction. These were positioned (Figure 1) using a Differential Global Positioning System (DGPS) approximately 1.5 kilometres offshore. Both current meters were moored 1.2m above the sea floor on stainless steel frames in water depth of ~4m at low tide. Cycle times were set to capture as much data as possible over the longest possible period. The S4adw has 20 megabytes of memory, as opposed to the S4dw's 1 megabyte, so the timings in Table 1 were used. The S4dw was deployed as a back up for the S4adw due to circumstances causing loss of data on previous S4adw deployments.

	Deployment	Cycle	On
S4adw	26/3/97 – 23/4/97	30 Min	5 Min
S4dw	10/4/97 – 23/4/97	60 Min	3 Min

Table 1 Current meter settings

A deployment of a S4adw current meter in continuous mode was also undertaken during a deep depression in the early hours of June 2 1997. However, forecasts of strong winds during the day did not eventuate resulting in no significant storm surge. This data is yet to be analysed

Longer term data from Environment Waikato wave and tide recorder at Tararu on the eastern side of the Firth of Thames were not available at time of print.

RESULTS

A Matlab program, ROSES, was developed by Rick Liefting to generate rose diagrams for wind data. ROSES may also produce similar plots for current direction/speed and wave direction/height.

Long-term wind data (Figure 2) does not adequately represent the significance of storm events (such as cyclones Drena, Fergus and Gavin), as storms are short term and their associated high winds represent <1% of the overall wind speeds. Frequencies of occurrences <1% are disregarded in ROSES plots.

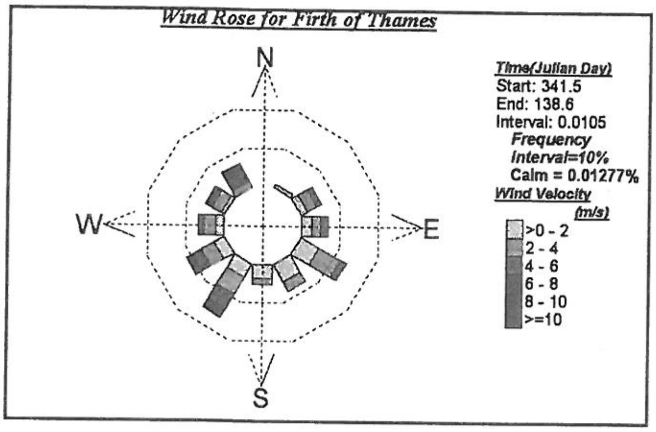

Figure 2 Wind rose for the Firth of Thames from December 9 1996 to May 18 1997.

Long term wind data shows light to moderate winds from a range of directions. The predominant wind directions are from northwest to southwest.

Due to the shape of the Firth of Thames, there is a considerably longer fetch in the north–south direction as opposed to the east–west direction. Therefore, along the Kaiaua-Miranda coast, at the southern end of the Firth, northerly winds generate the largest waves. Due to a variety of problems, storm surge waves have not been able to be measured by the instruments deployed near Kaiaua.

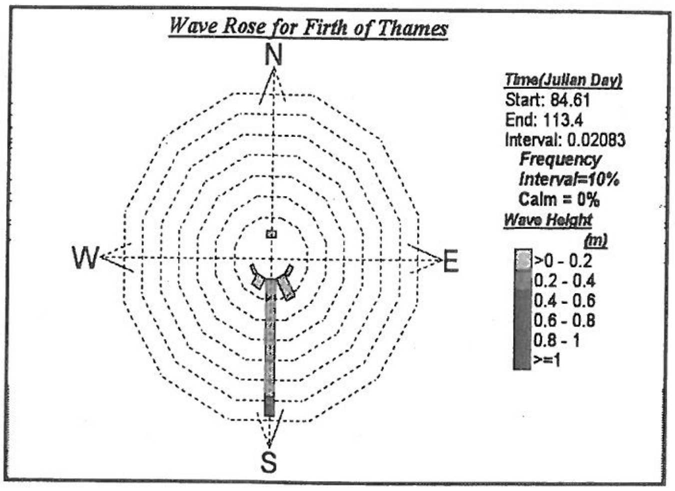

Figure 3 Wave rose for the Firth of Thames from March 26 1997 to April 23 1997

However, the available measurements indicate that the overall wave climate is very low energy.

Figure 3 shows a predominantly southerly wave direction (180^0) with a mean significant wave height of 0.1240m, mean period of 3s (Figure 4) with corresponding mean frequency of 0.3Hz.

STORM EFFECTS

The combination of northerlies, high tides and low air pressure (storm surge) produce greater sea gradients and wave set-up, causing inundation of unprotected coastal areas. Cyclone Drena caused substantial flooding and destruction along the Thames Coast (eastern coastline of the Firth of Thames), particularly at Moanatairi near Thames. Flooding and road closures also occurred along the Miranda – Kaiaua coastline (western coastline of the Firth of Thames). Although the high winds and rain during Cyclone Drena occurred from Friday 10 of January until Saturday 11 of January, major inundation occurred in combination with a high spring tide on the morning of the 11th. Persistent northerly winds (Figure 5) increased the amount of water in the southern Firth of Thames causing more water to be driven ashore and greater wave run up due to the increased water level.

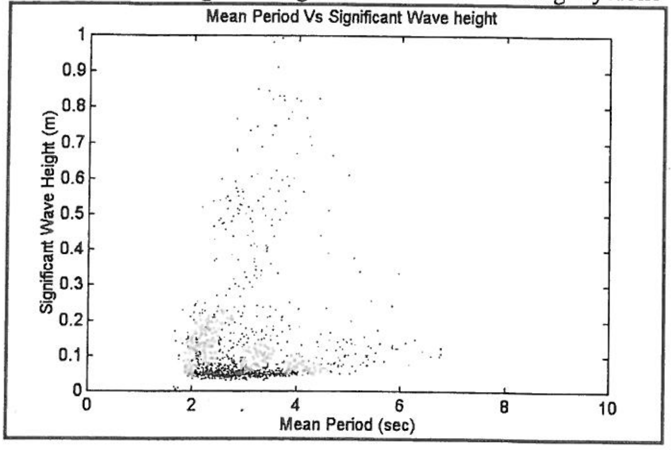

Figure 4 Mean period versus significant wave height for the Firth of Thames from March 26 1997 to April 23 1997

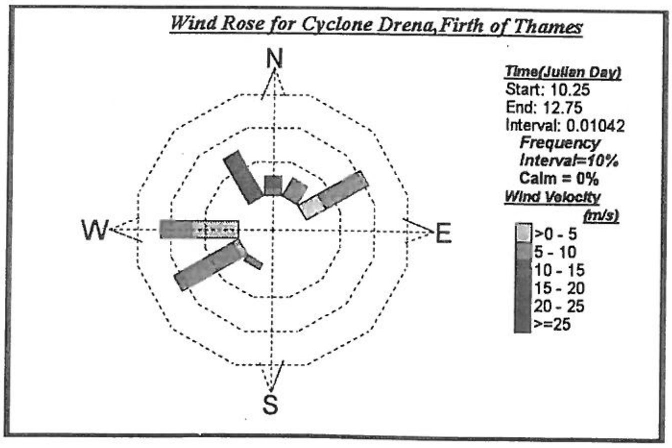

Figure 5 Wind rose for Cyclone Drena, Firth of Thames from 10 January to 12 January 1997

The raised water level and increased wave energy caused the predominantly shell berm to be washed over, increasing the width of the chenier ridge landward. Later observations showed that a new shell berm had been formed by lower energy waves that predominantly occur in the Firth of Thames.

FUTURE WORK

A Klein 595 Side-scan Sonar will be used to identify bedforms, shell beds and shell deposits along the Kaiaua – Miranda coast. The side scanning area will be directly offshore from the modern chenier ridge, up to a kilometre from the coastline. SCUBA divers will be used to clarify any unknown features from the side scan trace. The seabed texture in this area has been analysed by several different studies (Rodjso 1995). However, during the deployment of the instruments off Kaiaua it became apparent that there had been major changes in the surficial sediment characteristics. The purpose of the side scan survey is to document these changes, and to assess the significance of the offshore area as a source of the shell material present in the chenier ridges.

Pressure wave recorders (Dobies) will be set up in a transect perpendicular to the modern chenier to measure wave energy dissipation across the intertidal flats. In particular the effect of changing water levels on wave energy propagation will be assessed. Surveyed profiles across the modern chenier ridge will be obtained over time to measure chenier dimensions and relative position. In particular the rate of migration and the elevation changes in response to storm and 'fair weather' events will be assessed.

Finally, hydrodynamic numerical modelling of the Firth of Thames will be attained using the hydrodynamic model 3DD (Black 1995). 3DD is a 2 or 3 dimensional model which simulates the hydrodynamic process of circulation and transport. The fundamental equations of *momentum* in the x and y direction (Equations 1 and 2)

$$\frac{\partial u}{\partial t}+\frac{u\partial u}{\partial x}+\frac{v\partial u}{\partial y}-fv=-\frac{g\partial\zeta}{\partial x}-\frac{1\partial Patm}{\rho\partial x}+\frac{\rho a\gamma Wx\,|W|}{\rho(d+\zeta)}-\frac{gu(u^2+v^2)^{1/2}}{C^2h}+A_H\left(\frac{\partial^2u}{\partial x^2}+\frac{\partial^2u}{\partial y^2}\right) \quad (1)$$

$$\frac{\partial v}{\partial t}+\frac{u\partial v}{\partial x}+\frac{v\partial v}{\partial y}-fu=-\frac{g\partial\zeta}{\partial y}-\frac{1\partial Patm}{\rho\partial y}+\frac{\rho a\gamma Wy\,|W|}{\rho(d+\zeta)}-\frac{gv(u^2+v^2)^{1/2}}{C^2h}+A_H\left(\frac{\partial^2v}{\partial x^2}+\frac{\partial^2v}{\partial y^2}\right) \quad (2)$$

and *mass conservation* (Equation 3)

$$\frac{\partial\zeta}{\partial t}+\frac{\partial}{\partial x}(d+\zeta)u+\frac{\partial}{\partial y}(d+\zeta)v=0 \quad (3)$$

are used in describing the acceleration/retardation of the water body caused by forces and friction of the water body. Where t is time, u, v are horizontal velocities in the x, y directions, h is depth, g the gravitational acceleration, ζ the sea level above a horizontal datum, f the Coriolis parameter, P is pressure, C is Chezy's C and A_H the horizontal eddy viscosity coefficient.

The model bathymetry and dimensions are derived from the calibrated 3DD numerical model used in the Nearshore Offshore Exchange (NOSEX) programme undertaken by the National Institute for Water and Atmospheric Research (NIWA) and University of Waikato (Black, Bell and Oldman 1996). The model grid consists of 65 x 105 cells, each cell being 1500m x 1500m.

The wave and current model WBEND will be used to model propagation of waves within the Firth of Thames. Using wind and atmospheric data, numerical models of a number of storm events can be produced and compared with actual data.

From these simulations and the observational data a numerical model of chenier formation will be developed.. Once calibrated, the chenier model will be used to determine historical storm events from the dimensions of intact, relict, chenier ridges.

CONCLUSION

The Firth of Thames is a predominantly low energy environment. However, storm events producing northerly winds drive water southwards increasing the local water level and causing increased wave energy. This wave energy is dissipated along low lying, unprotected coastlines causing flooding and damage.

Although there is no wave data recorded for a major storm event, such as cyclone Drena, atmospheric data from Drena and other storm events will be used to numerically model wave propagation in the Firth of Thames during storm events. It is increased wave energy and short term sealevel elevation due to storm events (storm surge) in conjunction with long periods of low wave energy that drives chenier ridge formation.

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