Morphological changes for southeastern Matakana Island (Panepane Point) and Matakana Banks (ebb tidal delta) 2016-22

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Executive summary

Multibeam echosounder surveys of the ebb tidal delta (Matakana Banks) show ongoing migration of swash bars on the swash platform driven by changing weather and tidal conditions. Overall there is no long-term trend for erosion or accretion, apart for a slow accumulation of sediment on the terminal lobe, particularly where it connects with the surf zone along the Matakana Island shoreline.

Surveys of the mean high-water mark since 1992 indicate a continuing trend since April 2000 for erosion affecting the southeastern ~1 km of Matakana Island, and extending ~400 m into the harbour. The spit tip has migrated into the harbour, and is associated with accretion inside the harbour.

The overall erosion trend at the spit tip is associated with the ongoing evolution of Panepane Point, and appears to be primarily in response to storms, particularly those with northeasterly gale-force winds that produce maximum wave heights during late flood tide. The observed erosion is not threatening areas landward of the 1922 shoreline, and erosion since the previous report is minor. A shallow flood tide channel has formed along the seaward margin of Panepane.

The observed changes are consistent with patterns observed before the first capital dredging programme, and suggest that there is likely to be a return to further accretion assuming continued sediment availability. There will continue to be limits on the maximum distance the spit can migrate towards Mauao due to the tidal flows through the inlet that transfer sediment into the harbour.

Introduction

The Port of Tauranga Ltd is required to undertake monitoring of the Matakana shoreline to identify any erosion that could threaten areas of cultural significance that lie landward of the historic 1922 shoreline. de Lange and Moon (2017), de Lange and Moon (2018), and de Lange (2019; 2020; 2021) reported on comparisons of survey data undertaken before and after capital dredging during 2015-2016 and 2016-2021. These reports identified that the largest changes occurred at Panepane Point, and that observed changes were consistent with historic trends. However, changes of the shape of the spit at Panepane Point were also consistent with predicted and observed changes in current flows around the spit. This report reviews additional observations obtained since 2021.

Shoreline changes at Panepane Point

Figure 1 compares the surveyed positions of the High-Water mark (HW) between 2015 and 2022. It is evident that recent erosion of the tip of Panepane Point is still restricted to ~1 km of shoreline on the open coast and ~400 m inside Tauranga Harbour, and does not reach the position of the 1922 shoreline. The largest change has been 75-80 m retreat of the shoreline north of the spit tip from 2015 to 2021, mostly between March 2018 and April 2021. This has been associated with a migration of the spit tip into the harbour since April 2020. Between April 2021 and May 2022, there has been further erosion of the seaward margin and accretion on the harbour margin. However, the amount of change is less than observed during the surveys between March 2018 and April 2021.

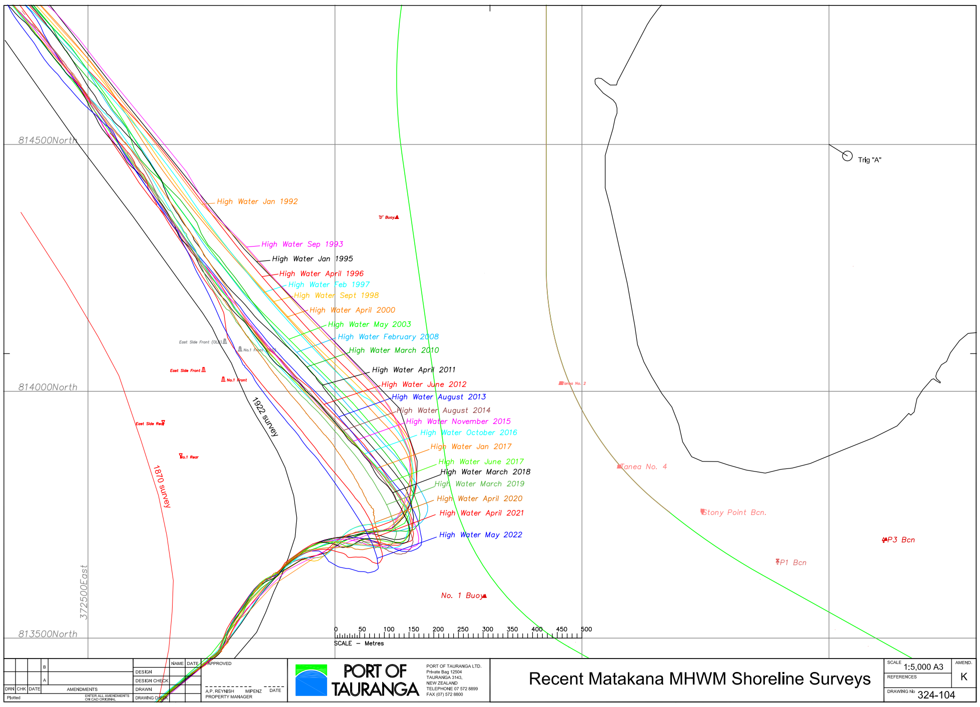

Figure 1. Comparison of high-water mark locations for southeastern Matakana Island between January 1992 and May 2022. Figure provided by Greg Cox, GJC Consulting.

Figure 2 shows the bathymetry of the Matakana Banks ebb tidal delta as surveyed in April 2022 superimposed on hydrographic chart NZ5412. There are no obvious changes evident at the resolution of this image compared to the previous survey in April 2021. The numerical data indicate minor spatial fluctuations over the delta associated with small shifts in the locations of swash bars as discussed in previous reports (*viz*. de Lange, 2020; 2021).

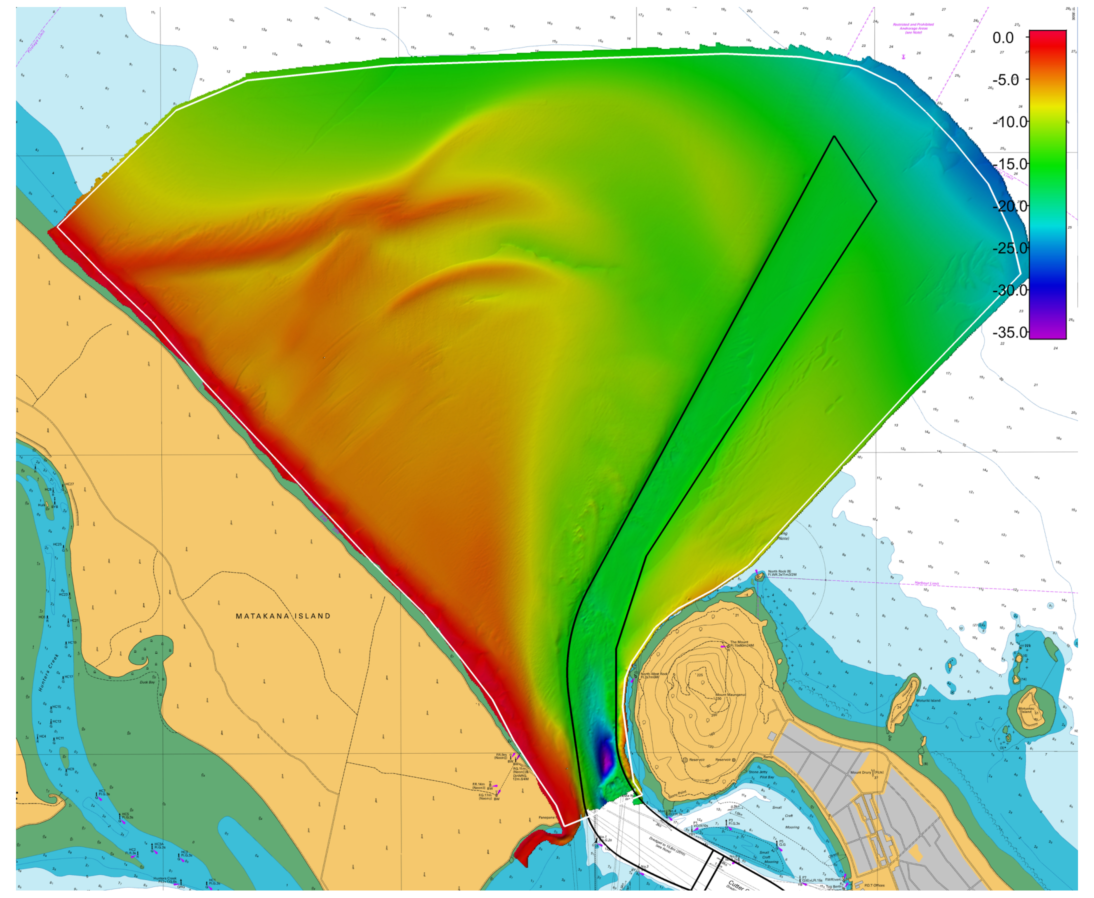

Figure 2. MBES bathymetry for the ebb tidal delta (Matakana Banks) and the Tauranga Harbour tidal inlet gorge collected in April 2022 superimposed on chart NZ5412. Figure provided by Discovery Marine Limited (DML).

Given the proximity of the erosion to the shipping channels and the capital dredging that occurred in 2015-16, the obvious question is what contribution, if any, the dredging has had on the observed erosion. This requires looking more closely at the pattern of erosion.

Figure 3 compares the positions of the shoreline (2010-2021) and several depth contours at Panepane (2007-2021) to illustrate the variation in the extent of erosion at different depths along the shoreline. It is clear that the erosion has mostly occurred above chart datum, and predominantly above the mean high water level. The margins of the shipping channel at depths of 5 m or greater have not shifted significantly, while the 2 m depth contour has moved, but much less than the shallower contours. The lack of movement of the deeper contours is due to the presence of resistant materials at those depths, while the overlying sand at shallow depths is more mobile.

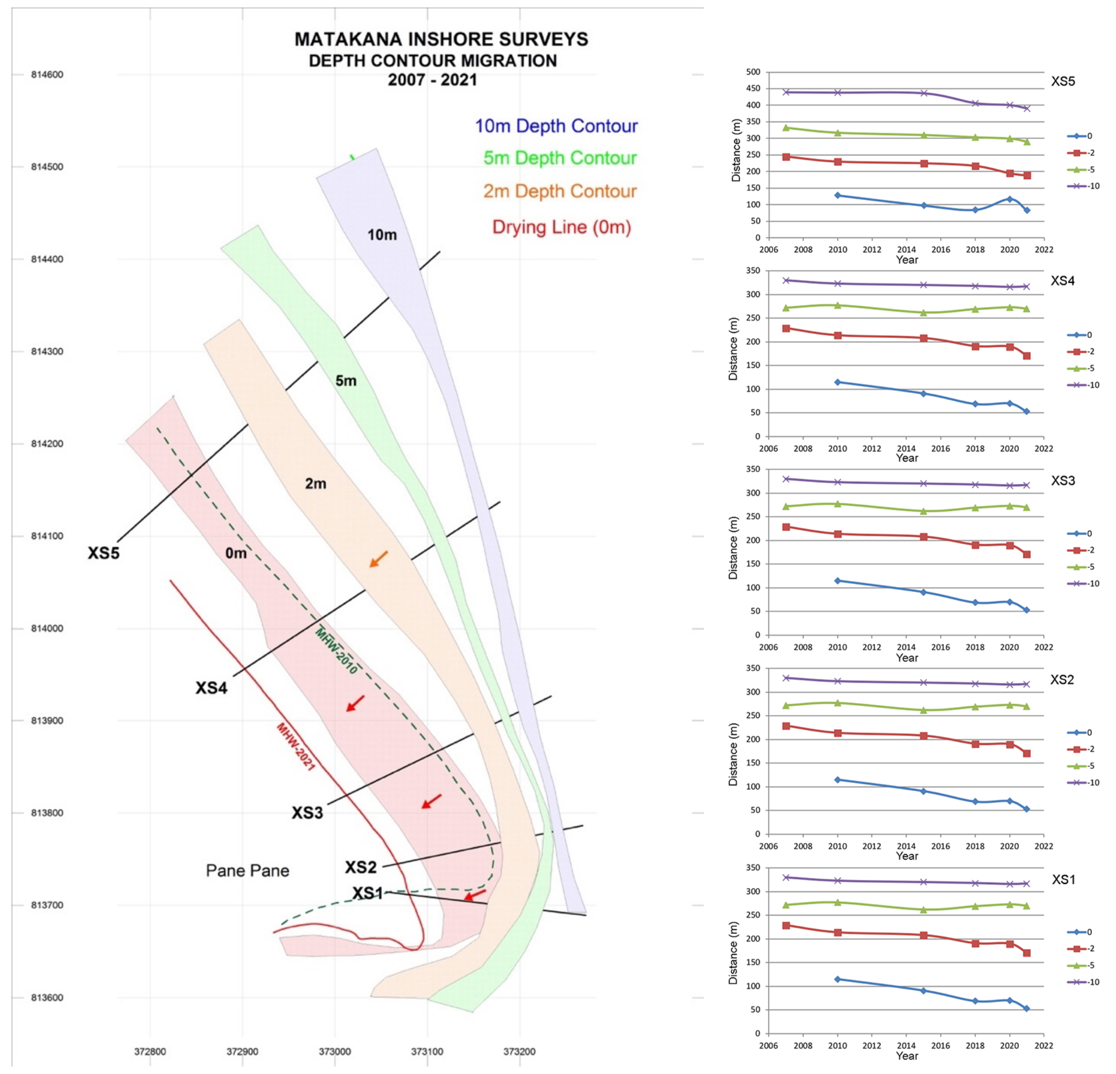

Figure 3. Migration of selected depth contours at Panepane, Matakana Island, between 2007, before capital dredging, and 2021, after capital dredging. Left-hand image is a plan view with the shaded areas representing the maximum excursions for each depth contour, while the right-hand images are time-series of excursion distances for the transects XS1-5. Figures and data provided by Greg Cox, GJC Consulting.

The changes illustrated in Figure 3 are evidence that the tidal currents, which are strongest at depths >5 m in the entrance, are not driving the erosion. The maximum changes occur at chart datum, which corresponds to the lowest astronomical tide (LAT). The 10 m contour that is located closest to the shipping channel shows little change close to the narrowest part of the entrance, which the location of the maximum tidal flows. The largest changes at 10 m depth occur north of transect XS5, which is furthest from the dredged shipping channel and in an area where flow measurements indicate that the strength and orientation of the ebb-tidal jet naturally varies over monthly to decadal time scales. The right-hand images also show a long-term trend of movement that preceded the capital dredging, and accelerated near the spit tip during 2019-2020.

Figure 4 compares Google Earth images from June 2018 and January 2022. A zone of erosion of the lower part of the beach was apparent in June 2018 extending for the area marked by the yellow arrow to the No 1 reach leading marks. The January 2022 image shows that entire beach has changed, with the damp low tide platform no longer visible due to a change in the beach profile, and the loss of dunes along the shoreline. Most of the dune erosion has occurred from the area just northwest of the leading lights to the spit tip.

Figure 4. Google Earth images for June 2018 and January 2022 that bracket the erosion event at Panepane, Matakana Island, resulting in the relocation of the No 1 Front light ~75 m further inland. Note the initial erosion at the location marked by an arrow in June 2018, and the marginal flood channel developed by January 2022.

An interesting feature is the development of a marginal flood channel along the shoreline at the spit tip, as evident in the January 2022 Google Earth image (Figure 4). This channel is most important near low tide as the ebb tidal jet weakens, allowing a flood flow to become established at the margins of the ebb jet. This flow on the western side of the ebb jet is concentrated into the marginal flood channel, and transports sediment into the harbour as shown by the flood-directed bedforms. Once a flood jet is established during the rising tide, the flow in the channel decreases significantly.

Aerial photographs of the Tauranga Harbour Entrance since 1943 show that the pattern of erosion and development of a marginal flood channel on the seaward side of Panepane has occurred before (Figure 5). In 1943 an existing marginal flood channel is infilling creating a small impoundment at low tide. By 1953 a new marginal flood channel is forming, and is separated from the main channel by three small sand banks. By 1959 the spit tip has eroded and the harbour entrance has widened, with a wide shallow marginal flood channel present. A small sand bank is forming at the harbour end of the marginal channel in response to ebb flows from the Lower Western Channel. All of these changes occurred before the first capital dredging began in 1968. The final photo in Figure 5 is from 1978 and shows the accretion of Panepane has buried the two sets of flood marginal flood channels that formed before 1959.

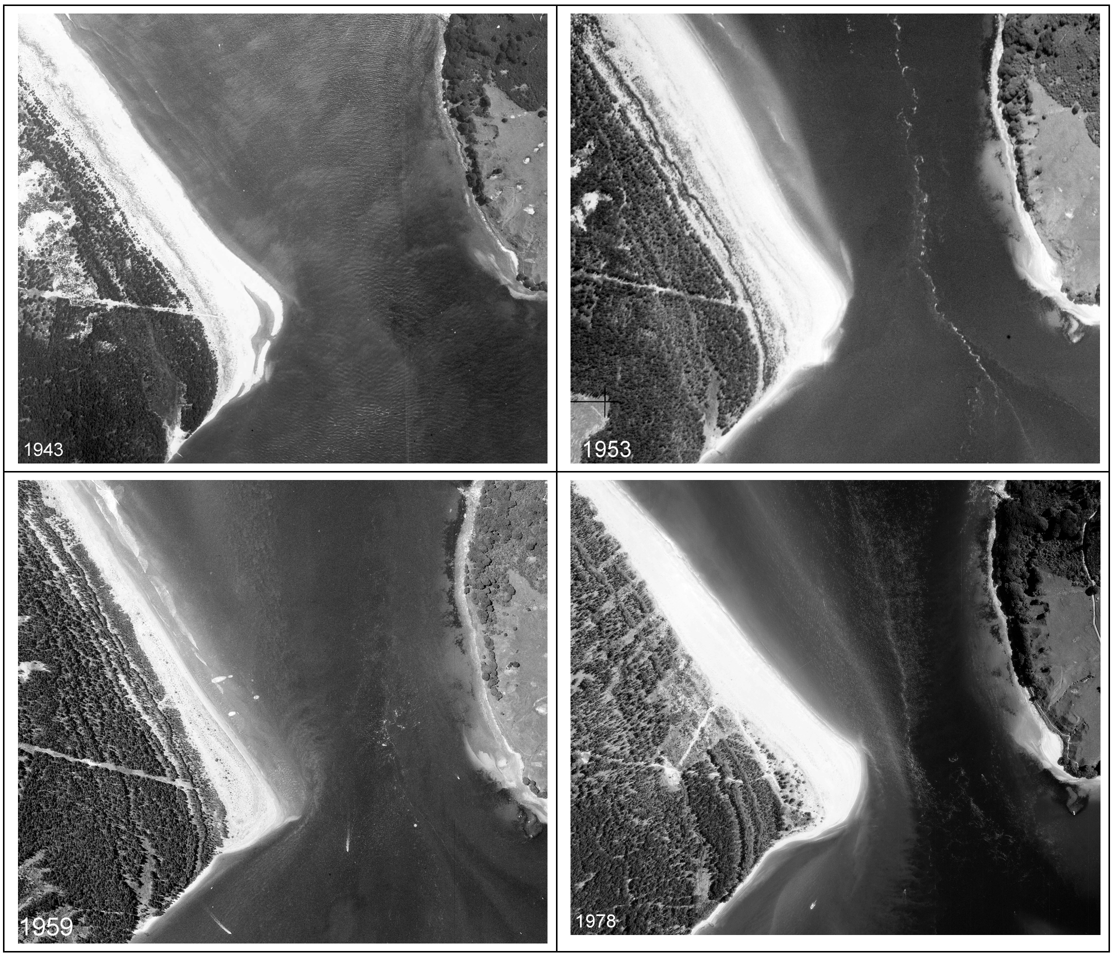

Figure 5. Aerial photographs of the entrance to Tauranga Harbour showing changes to Panepane associated with the formation and burial of a marginal flood channel on the seaward side of the spit.

Although marginal flood channels are named in recognition of their role in tidal flows associated with ebb tidal deltas, their development and behaviour is strongly to predominantly controlled by wave activity. Waves entrain sediment, and also generate longshore currents that reinforce or inhibit the flood tidal flows. It is generally recognised that wave activity is the main control on the shape of the spits associated with ebb tidal deltas, and therefore play the main role in erosion and accretion of the shoreline.

For the Matakana Banks ebb tidal delta, Ramli (2016) is the most recent study of a series of field investigations and modelling studies, going back to the physical modelling of the harbour undertaken by the Wallingford Hydraulics Laboratory in the early 1960s (Hydraulics Research Station, 1963; 1968). Interestingly, none of these studies identified the presence of a marginal flood channel along the Panepane shoreline as evident in the 1959 and 2022 photographs (Figures 4 & 5). This suggests that the development of such a channel occurs rarely.

Ramli (2016) showed that the movement of swash bars on the ebb-tidal swash platform changed the behaviour of the ebb jet and associated tidal eddy (and hence the early flood flow along the Panepane shoreline), and also wave refraction and other shoaling effects across the ebb tidal delta. Ramli (2016) found that a major driver of the changing positions of the sand bars was the shift in wave conditions with the El Niño-Southern Oscillation (ENSO), particularly during the extremes (El Niño and La Niña). The changing wave climate and the effects on an ebb tidal delta and adjacent shoreline had previously been recognised for the Katikati Entrance of Te Awanui/Tauranga Harbour by Macky *et al* (1995) and Hicks *et al* (1999) respectively.

Observations suggest the direction of sand transport along the Matakana Island shoreline switches in response to ENSO so that Waikoura (Katikati Entrance) tends to erode while Panepane (Tauranga Entrance) accretes, and vice versa. La Niña conditions tend to increase wave erosion at Panepane, and Figure 6 shows that La Niña conditions have occurred frequently since the 2015-2016 Capital Dredging Programme, and in 2022 a strong La Niña developed after 2 years of weaker La Niña conditions. Changes in ocean circulation in 1998 associated with the Pacific Decadal Oscillation (also known as the Interdecadal Pacific Oscillation) favour La Niña conditions. This oscillation is likely to switch before 2030 to a pattern that favours El Niño conditions.

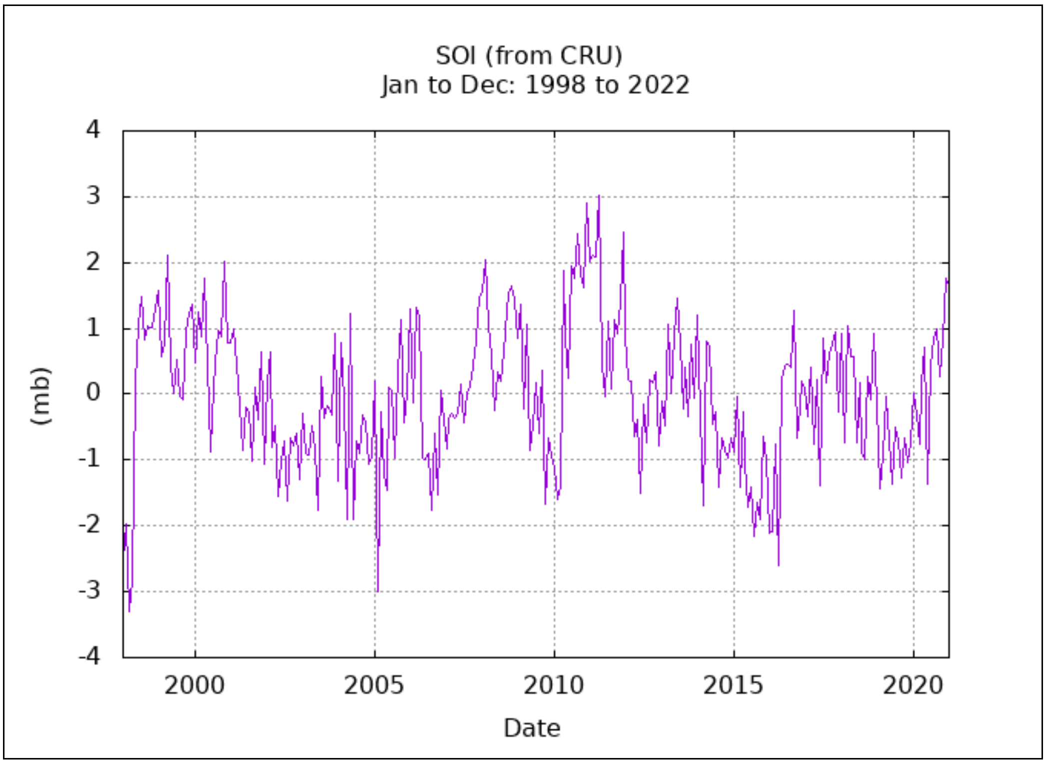

Figure 6. Southern Oscillation Index from 1998 to 2022. Negative values correspond to El Niño and positive values to La Niña.

Modelling by Ramli (2016) suggests that the movement of the swash bars would result in localised focussing of wave energy creating embayments as evident at the arrowed location in June 2018 (Figure 4). This location has developed erosional embayments previously, such as in 2005, that have subsequently recovered.

However, her modelling did not predict the formation of the marginal flood channel, or the extensive loss of frontal dunes and spit tip observed recently. Modelling of wave effects for Matakana Island, and Panepane specifically, has not been done, but various studies have examined wave behaviour at dredge spoil disposal sites and for surfing conditions between Ocean Beach, Mt Maunganui, and Papamoa (Scarfe, 2008). These studies indicate that Panepane is normally sheltered from large waves by Matakana Banks to the north and west, and Mauao to the east and north east (Figure 7).

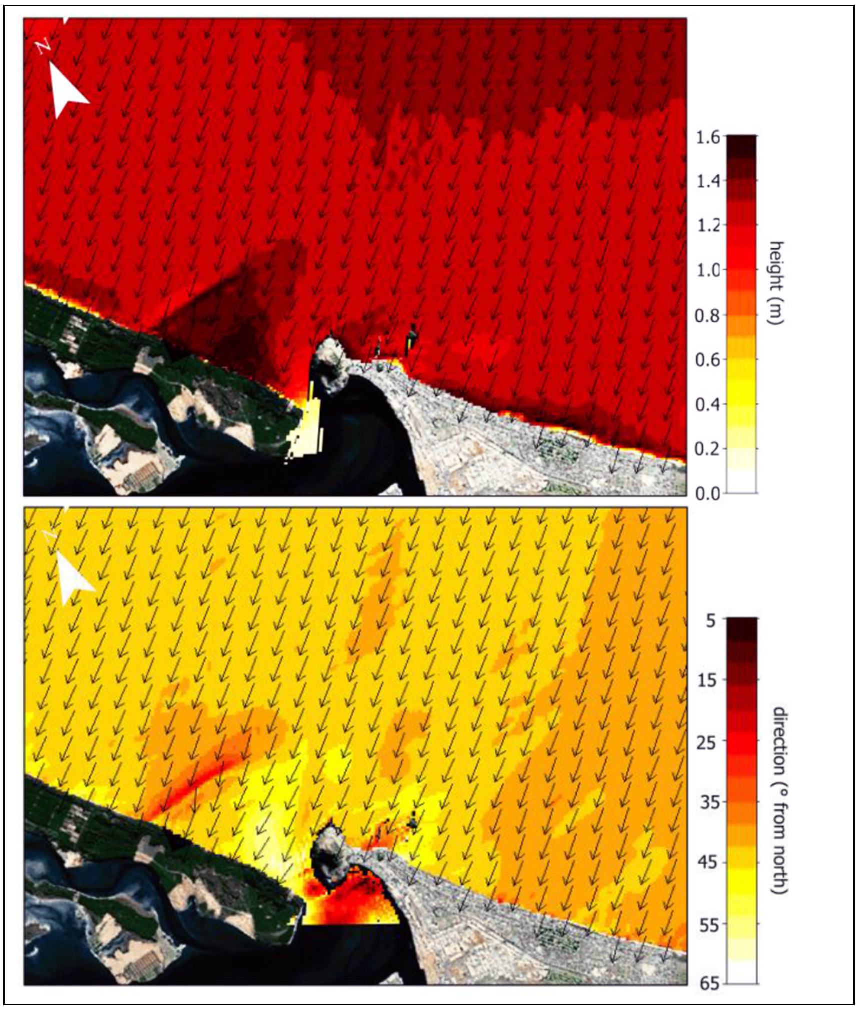

Figure 7. Effect of bathymetry and offshore islands on wave heights and angles for a surfing wave event on the Mount Maunganui (Scarfe, 2008).

There is a narrow window from the north-northeast that does allow larger waves to approach Panepane, but that situation is unusual as offshore islands (particularly Motiti Island) and East Cape restrict deep-water wave approach from that direction (Figure 9). The importance of waves approaching from a specific direction is also supported by the effects of the most severe storms since

1950: Extratropical storm Giselle in April 1968, extratropical storm Bola in March 1988, and an unnamed winter storm in July 2007. All three storms produced strong winds within the Bay of Plenty for 36-48 hours, which generated large waves (Figure 8). These storms correspond to design conditions used for the coastal structures in the Bay of Plenty as they have annual exceedance probabilities of <2%.

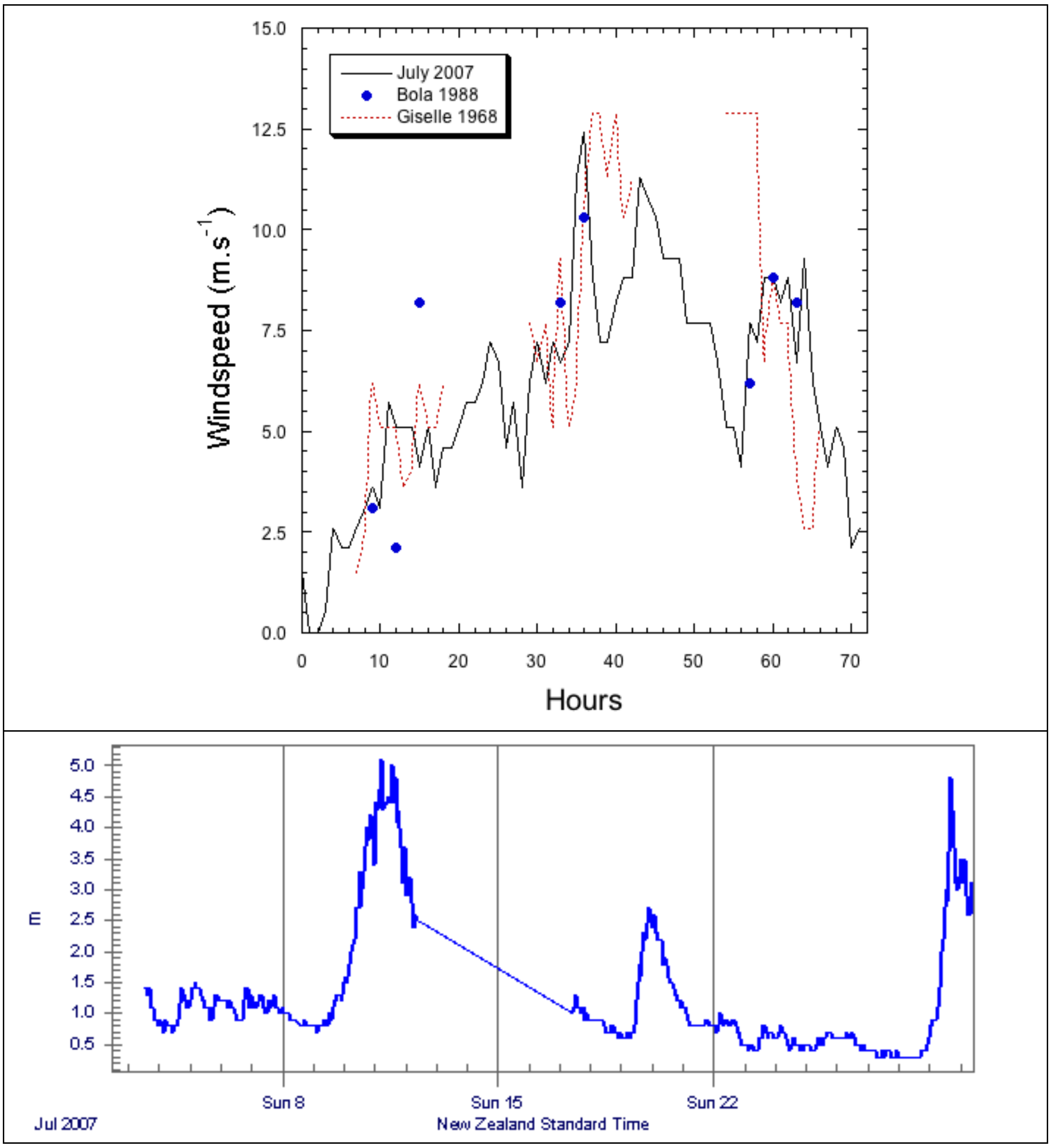

Figure 8. (Top) Windspeeds recorded at Tauranga during extratropical storms Giselle (1968) and Bola (1988), and an unnamed winter storm (2007); and (Bottom) significant wave heights recorded by the Pukehina wave buoy during July 2007.

The three storms generated a similar distribution of wind speeds over a 3 day (72 hour) period (Figure 8 top), and based on media reports and empirical predictions, produced similar distributions of wave heights to the measured waves in July 2007 (Figure 8 bottom). However, Giselle in 1968 caused widespread erosion around the Bay of Plenty, while Bola and the July 2007 storm caused localised erosion and also created localised accretion. For example, the stretch of coast between Mauao and Papamoa largely accreted during the July 2007 storm, although there were localised areas of erosion (mostly around structures such as storm water outfalls and stairs). There appears to be no observations for Matakana Island, and Panepane specifically. Aerial photographs and Google Earth images do not show erosion, but they are widely spaced in time and do not constitute conclusive evidence.

Numerical modelling of the July 2007 storm (Figure 9) showed that the largest waves reached the shore between Waihi Beach north and Omanu, and that wave heights and directions were strongly modified by offshore islands and reefs. For this storm Panepane was sheltered by Mauao. However, this modelling suggests that a storm with a strong easterly wind component could result in Motiti Island focussing wave energy on the eastern side of the ebb tidal delta (Matakana Banks), where it can refract and diffract, due to a combination of bathymetry and strong flood tidal currents, onto Panepane.

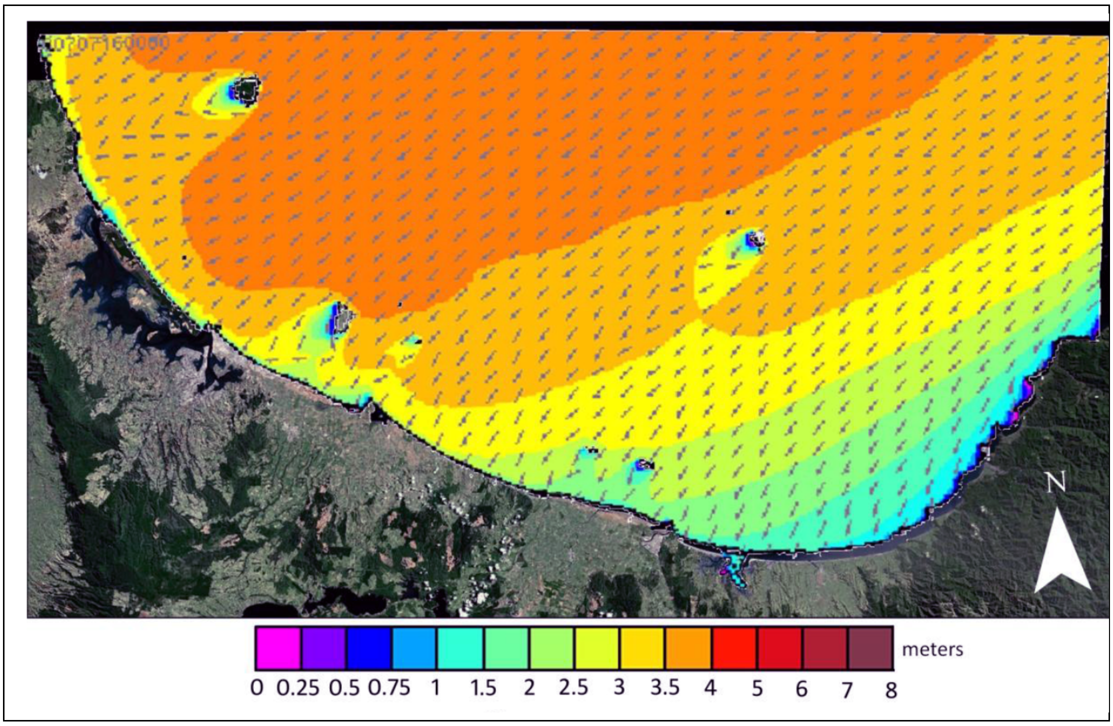

Figure 9. SWAN modelling of offshore wave heights (coloured contours) and directions (arrows) during storm on 16 July 2007 (Scarfe, 2008).

The Port of Tauranga Ltd operates a video camera on Panepane that collects a still image of the shoreline every half an hour during daylight hours, and collects wave height and period data at A Beacon at the entrance to the harbour. Figure 10 shows the video image near the peak of a storm on 1 June 2020 that caused up to 10 m of shoreline retreat within the camera field of view, and the significant wave data from A Beacon and the Bowentown wave buoy operated by the Bay of Plenty Regional Council. The maximum wave height and largest significant wave height recorded at A Beacon were 8.87 m at 12:36 pm and 4.54 m at 12:35 pm respectively (Figure 10). High tide occurred at 2:26 pm, with a predicted elevation of 1.84 m. The video images indicate that sea level was elevated above the predicted tidal elevations due to a storm surge and wave set up.

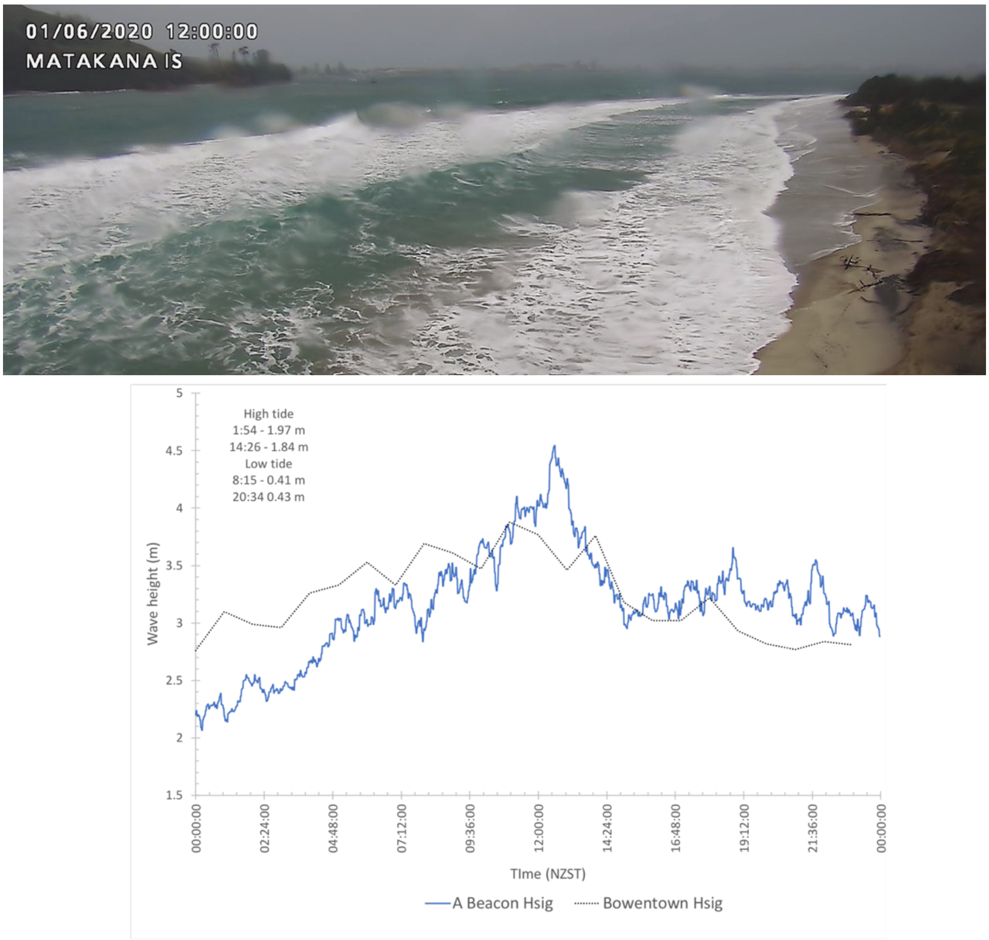

Figure 7. Video still image of Panepane at midday, and significant wave height recorded at A Beacon (Port of Tauranga Ltd) and the Bowentown wave buoy (Bay of Plenty Regional Council) during a storm on 1 June 2020. The video camera connection was damaged by the storm resulting in loss of data, including half the midday image and the 12:30 image at the peak of the storm waves.

The A Beacon wave recorder does not measure the wave direction. However, Bay of Plenty Regional Council maintain directional wave buoys offshore from Pukehina and Bowentown (Katikati entrance to Te Awanui). Directional wave data collected by the University of Waikato at A Beacon while a waverider buoy was deployed off the Katikati ebb tidal delta (Macky *et al*, 1995) indicated that the wave directions were similar between these two locations. The Bowentown wave buoy measured a mean direction of 50.3° (NE) with a range of 43° to 61°. The Pukehina wave buoy operated by the Bay of Plenty Regional Council was not working during this storm, so there are no other measurements of the wave directions. If the same direction occurred at Tauranga as at Bowentown, Panepane was not directly exposed to the storm waves.

However, with the Entrance Channel orientated at 29°, it is possible that some wave energy was transmitted to Panepane via the deep channel. However, the orientation of the waves in the video image indicate that most or all of the wave energy is associated with storm waves refracted around Mauao over the eastern margin of the ebb tidal delta, and diffracted into the wave shadow zone, probably due to the influence of the flood tidal currents enhanced by a storm surge. There have been no studies published of the wave-current interactions within the Tauranga Harbour Entrance and the impacts on the shoreline and harbour, although de Lange (1988) did observe that long-period swell energy did propagate into the harbour with a tidal influence on the quantity of energy and associated periods (flood tides increased both the energy and period).

Given the role of waves and the variations associated with climatic oscillations in the past (for example ENSO and the Pacific Decadal Oscillation), it is likely that the transport of sand along the Matakana Island shoreline will switch again resulting in accretion at Panepane. This will depend on the availability of sediment from sources such as the swash bars on the ebb tidal delta, and from longshore transport along the Matakana Island shoreline. Bear (2009) found that sediment is still being transferred to the beach from the inner shelf at Waihi Beach, and Ramli (2016) showed that sediment from the inner shelf near the Matakana Banks ebb-tidal delta may also be transferred shoreward.

Kulgemeyer *et al* (2016) and Kulgemeyer *et al* (2017) showed that sediment is transported towards the northwest at depths ~35 m along the inner shelf from the area offshore from the Kaituna River. Some of the disposal sites used by the Port of Tauranga lie within the zone of north-westward sediment transport, which raises the possibility that the dredged sediment may add to the natural sediment supply.

In my opinion, it is likely that there will be a switch to an accretionary phase that replaces the sediment lost during the recent storm erosion. The accumulation of sediment could be enhanced by establishing native foredune vegetation (viz. Muller, 2011; Jenks, 2018). There is a limit to the extent Panepane can accrete eastwards, as the tidal flows through the entrance will erode any sediment deposited beyond the resistant layers on the western margin of the channel. The eroded sediment will most likely be transported into the harbour.

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