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Whangamata ebb tidal delta morphology and wave breaking patterns

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Abstract
To examine the morphology of the ebb tidal delta (ETD) at Whangamata, 14 single beam bathymetric surveys, conducted from 19/07/2007 to 01/08/2012 on a 6 monthly basis, are analysed in conjunction with wave climate data. Whangamata ETD exhibits transitional morphological features characteristic of both wave and tide dominated ETDs. The persistence of these features shows a relationship to wave climate, particularly wave height. Wave conditions directly preceding bathymetric surveys coincide with particular morphological configurations with modifications most notable in the ETD's terminal lobe, channel margin linear bar and marginal flood channel. Peel angle is used as a proxy for surfability and shows that the main ETD features at Whangamata affecting surfability are the shape and orientation of the terminal lobe, delta front's southern margin and offshore leg of the marginal flood channel. Breaking patterns from Surveys 1 to 7 and 8 to 15 are dissimilar; the division coincides with the construction of a marina on the landward side of the inlet.

Keywords: morphology, wave breaking, surfability, ebb tidal delta

1. Introduction

Surfbreaks provide a source of recreation for an increasingly large number of participants and a site for professional competitions. Surfing has significant economic value to coastal communities [13], with surfing playing a key role in tourism [14], an industry which contributes approximately 23 billion NZD per annum [22].

Surfers require waves that 'peel' so that the breaking part of the wave translates laterally at a speed that can be matched by a wave rider. Surfers also require steep wave faces to produce high surfboard speeds [16]. Fundamentally, these two factors determine the quality of the waves for surfing and are both dependent, but not exclusively, on seabed morphology [17-19, 23, 24]. There is very little research directed toward how morphodynamics of an ebb tidal delta affect surfability.

This research examines morphological changes and wave breaking patterns Whangamata ebb tidal delta (ETD), which is one of New Zealand's 17 Nationally Significant Surfbreaks, as listed in the New Zealand Coastal Policy Statement 2010 [5]. The desired outcome of the work is to obtain a basic understanding of how seabed features change at the ETD and how this effects surfing wave quality.

2. Study Site

Whangamata is located on the Coromandel Peninsula, on the east coast of New Zealand. The ETD at Whangamata is a seaward extension of a sandy barrier spit (Figure 1). The spit is Holocene in origin and encloses a meso-tidal estuarine lagoon [21]. The lagoon is open to the Pacific Ocean through a small tidal inlet. North of the inlet is a rocky headland, Te Karaka Point, that acts as a static control point for the tidal channel, the result is a high-angle half delta [11].

Whangamata is prevalent with recreational boating, evident by the construction of a marina within the harbour. A navigation channel was excavated to access the marina from the main harbour channel. Periodic maintenance dredging of the navigation channel is required. Within the estuary there are large areas of mangrove, which thrive in the shallow, benign environment. Recently there has been removal of mangrove forests within the estuary and further removals are currently being considered.



Figure 1. Aerial photo of Whangamata Bay and Estuary (LINZ) located on the Coromandel Peninsular (insert).

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3. Methodology

15 bathymetric surveys have been conducted of the ETD between 19th July 2007 and 28th August 2012 [2, 3]. Table 1 lists the survey dates. Survey 9 data is not available for use and is therefore omitted from the study. The data was collected with a single beam echo sounder and RTK-GPS. The surveys have a common horizontal datum of New Zealand Geodetic Datum 2000. In addition to these localised surveys, a multibeam bathymetry survey was undertaken between the 26th and 28th of March 2012. This data has been merged with topographic and single beam bathymetric data collected on 1st July 2011, 8th August 2011 and 15th August 2011.

Table 1. Channel and ETD survey dates.

Survey #	Date
1	19/07/2007
2	4/12/2007
3	28/08/2008
4	20/11/2008
5	4/02/2009
6	5/06/2009
7	1/09/2009
8	20/11/2009
9	9/04/2010
10	31/05/2010
11	19/08/2010
12	1/04/2011
13	8/08/2011
14	15/02/2012
15	1/08/2012

The 14 ETD survey datasets are analysed in conjunction with inter-survey wave climate data. Wave breaking patterns are determined for each of the morphological states captured by the surveys using a phase resolving numerical model. Each of the 14 bathymetric datasets is interpolated on to a 5 m grid using a Kriging method. In order to numerically model the different bar states the model domain needs to extend beyond the ETD. To do this, the data from each of the 14 ETD surveys is integrated into the additional multibeam/topographic/single beam dataset, with a bias to maintaining the integrity of the ETD morphology captured by the survey. Hindcast data from Wavewatch III model output nodes located at 37°S / 176.5°E and 37.5°S / 176.5° E is modelled using SWAN over bathymetry from the GEBCO dataset. Wave data was extracted from the model results at 37.2°S / 175.9°E, some 1.6 km east of the ETD.

A 1 m at 10 s sinusoidal wave condition is used as a boundary condition to drive the model. A model domain is constructed for each of the 14 integrated datasets. Each model domain is capped on the north and south boundaries, which are lined with a 5 cell sponge, and the north eastern corner of the bathymetry, on the seaward side of Te Karaka Point, is blocked out for model stability.

Simulations are run at low water (CD + 0.2 m), which corresponds to optimal surfing conditions [20]. Wave breaking characteristics were quantified using wave peel angle [12, 23, 24] (Figure 2) after 15000 iterations to allow the model to stabilize. Peel angles from the first four wave crests, from the initial breakpoint, were measured (Figure3). The space in between the wave crests are referred to as 'sections', which is in line with surfing terminology and keeps the resulting descriptions concise.

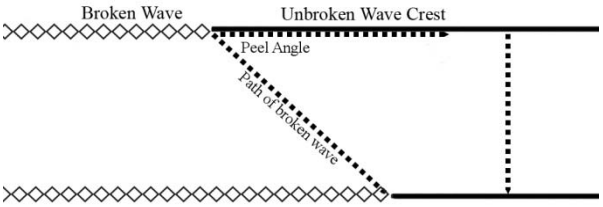

Figure 2. Schematic of wave peel angle. Peel angles of 0° indicate a wave that breaks along the length of the wave crest simultaneously. A peel angle of 90° describes a wave were breaking has initiated, but does not translate laterally along the wave crest.

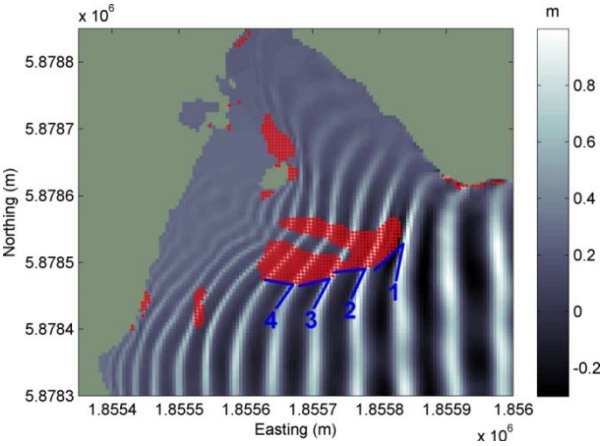

Figure 3. Example of peel angles sections annotated on model output of sea surface elevation with a breakpoint location overlay (red).

4. Results

4.1 Morphology and Wave Climate

Figure 4 shows gridded bathymetric data for each of the surveys and is available to view at: www.ecoast.co.nz/pubs/Atkin_etal13_supp.html. Here morphological changes are described relative to their preceding survey (excl. survey 1) using common ETD terminology (Figure 5), and significant wave height (H_s) (Figure 6). In the 21 days prior to Surveys 1, 6, 7, 10, 13 and 15 values of H_s exceeded 2.5 m (Figure 6). In Survey 1 the Channel Margin Linear Bar (CMLB) does not extend far offshore and feeds in to a longshore bar central to the delta front, which demarks the offshore extent of a well defined Marginal Flood Channel (MFC). The 2 m isobath depicts a round

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Terminal Lobe (TL). In Survey 6 the TL has a flatter profile that has shifted landward. The deep, wide MFC is filled in. In Survey 7 the TL remains flat in shape and has moved shoreward. There is no apparent MFC. In Survey 10 there is little change in the offshore position of the TL, and removal of material only along the northern and southern margins of the delta front. The CMLB is reduced in length. The MFC northern extension cuts through the coastal barrier end of the CMLB. In Survey 13 the TL is more rounded and the MFC has filled. In Survey 15 the 2 m contour of the TL moved shoreward by some 80 m. The CMLB has been substantially eroded at both the nearshore and offshore ends.

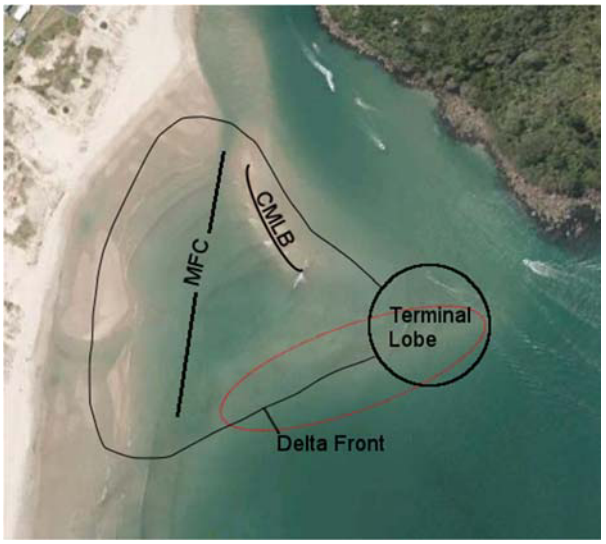

Figure 5. Annotated aerial photo of Whangamata ETD to indicate common features: delta front, terminal lobe, marginal flood channel (MFC) and channel margin linear bar (CMLB). The red ring approximate indicates the surfing area.

In the 21 days prior to Surveys 2, 4, 5, 8 and 14 values for H_s do not exceed 2 m (Figure 6). Survey 2 shows accretion of the CMLB and TL. The Marginal Flood Channel (MFC) re-orientates from being narrow and shore parallel to a wider, more rounded, shore-oblique feature in Survey 2. The MFC in Survey 2 intersects the western end of the southern prodelta slope. In Survey 4 the TL remains similar, but with more material further offshore. The CMLB returns to a more elongate form. The MFC is wide and rounded, obliquely orientated to the shoreline and positioned quite far out on the delta front. In Survey 5 the TL has an apex shape. The CMLB is not as pronounced and has eroded at the landward end. The MFC, is located central to the delta with the main offshore channel running shore-normal through the centre of the delta front. In Survey 8 the CMLB is very well established and extends far offshore, pushing the TL toward the east. On the southern side of the delta front an elongate bar with a WSW-ENE orientation, similar to that observed in Survey 5, protrudes from the shoreline. The MFC is central to the delta front and its offshore leg breaks the southern margin to the east. In Survey 14 the CMLB is long, well defined and shallow. There TL is narrow and elongate and further offshore. A large hole extends across the central part of the delta front. A wide channel on the seaward side of the MFC hole breaks the 1.8 m isobath along the delta's southern margin.

H_s in the 21 day period before Surveys 3, 11, and 12 all reached 2.3 m (Figure 6). In Survey 3 the TL is wider and flatter. The CMLB is less pronounced and disconnected from the shoreline. The MFC is more elongate, deeper and shore parallel. The offshore leg of the MFC is wider but remains in the west. In Survey 11 the TL is wider and flatter, the remnant CMLB is isolated and rotund, and the MFC is well defined with a narrow offshore channel. In Survey 12 there is no distinct CMLB, and the TL has a slight apex shape and has moved in shore. The MFC has roughly shore parallel but is wide to the north.

4.2 Wave Breaking

Table 2 presents peel angles from the first four successive wave crests associated with wave break points. There are several disparities in the peel angle results, some in certain sections, and others across all sections, on a survey to survey basis. The following are the most notable disparities. In section 1: from Survey 1 to 3 peel angles change from 31° to 70° to 38°; in Survey 7 the peel angle is 87°, in Survey 8 it is 32°; from Survey 13 to 15 the peel angle changes from 37° to 82° to 32°. In Section 2: from Survey 5 to 7 peel angles change from 70° to not breaking to 77°. From Survey 11 to Survey 13 the peel angle changes from 56° to 0° to 53°.

Table 2. Peel angle results for sections 1 to 4 for all survey configurations, sorted based on surfability.

Survey	Section Peel Angle (°)				Surfability
	1	2	3	4	
1	31	70	40	65	**5**
2	70	61	56	84	**7**
3	38	49	60	70	**1**
4	37	67	56	84	**3**
5	63	70	56	66	**6**
6	67	NB	55	55	**14**
7	87	77	67	11	**10**
8	32	70	90	NB	**8**
10	44	85	75	90	**9**
11	66	56	65	76	**4**
12	43	0	90	90	**13**
13	37	53	50	83	**2**
14	82	86	90	NB	**12**
15	32	90	72	90	**11**

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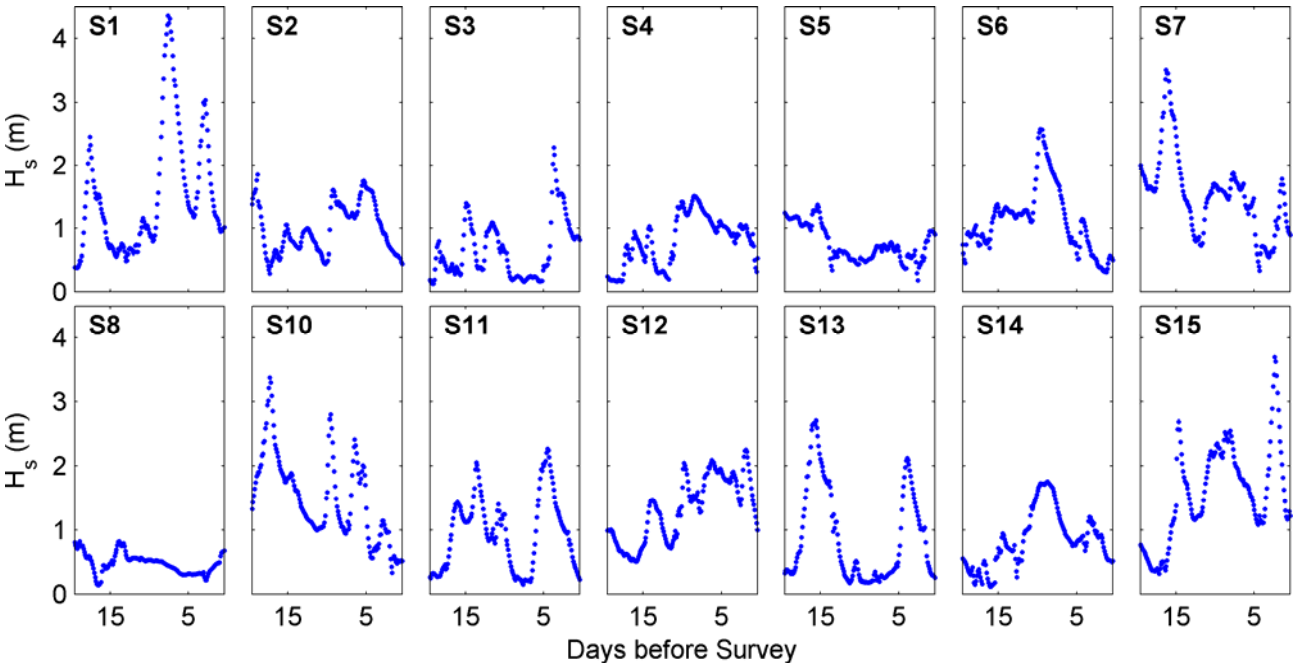

Figure 6. H_s values for the 21 days preceding each survey. Numbers along the top correspond to each survey.

Column 4 of Table 2 grades each bathymetric configuration in terms of surfability. The grading criteria is based on a body of scientific literature that objectively defines surfing wave quality [12, 23, 24], but also considers the consistency of peel angles across all four sections. Surveys 3, 4 and 13 provide, what are considered to be, the best bathymetric configurations conducive to high performance surfing. A morphological characteristic consistent with both Surveys 3 and 4 is that the offshore part of the MFC lies quite far to the west on the delta fronts southern margin, which accommodates consistency in the isobaths. The thalweg of the MFC runs on an approximately N-S axis in both cases. In Survey 13 there is no apparent MFC.

The lowest ranked succession of peel angles are produced in the Survey 6 case followed by Surveys 12 and 14. Survey 6 received the lowest ranking because no breaking occurred in section 2 due to the channel that runs shore normal through the centre of the delta, and just south of the terminal lobe. However, sections 1, 3 and 4 provided peel angles very conducive to surfing. In Survey 12 the offshore leg of the MFC is far to the west but southern margin gradients are low. In Survey 14 a large hole dominates the delta front and cuts the southern margin.

The peel angles conducive to high quality surfing are observed when the offshore channel is far to the west (Surveys 1, 3, 4 and 11), or not disturbing the southern margin (Survey 13) and the southern side of the TL (Survey 5). What seems most critical to overall surfability, using peel angle as a proxy, is the orientation and location of the MFC's offshore leg and the associated changes to the southern margin and TL. Where the offshore leg of the MFC cuts through either the centre of the delta and TL (Survey 6) or far to the east along the southern margin (Surveys 14 and 15), low ranked peel angles are observed.

There is an overall increase in peel angles of Section 3 for Surveys 8 to 15, compared to Surveys 1 to 7. The marina was constructed in November 2009, coincident with Survey 8. Increasing the tidal prism may have promoted tidal dominance and resulted in morphological configurations not conducive to high quality surfing waves [15]. However, within the group post marina construction surveys 11 and 13 rank within the top 5 bathymetric configurations conducive to high quality surfing.

5. Conclusion

From studying 6 monthly surveys it's observed that the ETD at Whangamata exhibits a range of morphological forms. Some features are persistent, while others are transient. Through an assessment of morphological features, the results suggest that the ETD at Whangamata undergoes periods of both tidal and wave dominance.

Peel angle has been used as a means of quantifying the breaking patterns and as a proxy for surfing wave quality. The different morphologies produce a range of breaking patterns that appear related to wave climate. Where wave heights are larger preceding surveys, i.e. a more wave dominated coast, the morphological configuration is more conducive to high quality surfing waves. Where wave heights are smaller and the coast is more tidally dominated the MFC disrupts the southern margin or terminal lobe of the ETD and reduces the quality of surfing waves.

Disparities in wave breaking patterns appear coincident with the construction of a marina in the harbour in November 2009. However, this study has not considered spring-neap tidal cycles proceeding surveys, related morphological changes to wave period and direction or looked at periodic dredging events associated with the marina development, nor other anthropogenic activity (e.g. mangrove removal). Furthermore, 6 monthly intervals are insufficient to confidently infer morphological response to forcing factors, but to date they are the only datasets available. Therefore, there is a requirement for further research to establish what the primary forcing factors are on morphological processes, how they directly affect ETD morphodynamics, and what this means in terms of surfing wave quality at this nationally significant surfbreak.

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