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Surf Zone Currents and Influence on Surfability

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Abstract

Surfing headlands are shallow and exposed coastal features that provide a specific form of breaking wave allowing a board-rider to ride on the unbroken wave face. The seabed shape and refraction of the waves in relation to depth contours provide the greatest influence on the quality of the surf break. The large scale and orientation of the Raglan headland allows only the low frequency swells to refract around the headland to create seven different surfing breaks. Each represents a compartmentalization of the shoreline along the headland. This creates variability in wave and current characteristics depending on the orientation and bathymetry at different locations. This provides not only potential access points through the surf-zone (ie: smaller currents), but greater surfability in a range of conditions that is not possible on small scale headlands.

Headlands with surfing waves can be classified as mis-aligned sections of the coast, where the higher oblique angle of the breaking surf generates strong wave-driven currents. These currents are far greater than that found on coastlines in equilibrium with the dominant swell direction, where comparatively insignificant longshore drift is found. The strength and direction of wave-driven currents in the surf zone can influence the surfability of a break. At a surfing headland strong currents flowing downdrift along the shoreline make it difficult for a paddling surfer to get to the "take-off" location of the break, or maintain position in the line-up. In comparison currents flowing updrift along headlands makes getting "out the back" relatively easy, although surfers can be taken out to sea past the “take-off” point by a fast flowing current.

Field experiments at Raglan, on the west coast of New Zealand have been conducted to measure current speed and direction during a large swell event. Observations of surfers attempting to paddle through the breaking-wave zone, confirms the strength of the wave-driven currents with surfers being swept rapidly down the headland. Results from the experiments at Raglan, have shown strong currents in the inshore breaking wave zone with burst-averaged velocities attaining 0.8 ms^{-1}, and maximum bed orbital velocities of up to 2.0 ms^{-1}. Interestingly, further offshore the currents have been found to flow in a re-circulating gyre back up the headland. Comparisons are made from observations of waves and currents found at other surfing headlands around the world. The effect that strong currents may have on the surfability of artificial surfing reefs needs to be considered in the design process, if the surfing amenity is to be maximised for large surf conditions.

1. INTRODUCTION

The saying that “headlands draw the waves” was known by many an old seafarer and was used in reference to the fact that wave energy is concentrated on these promontories, therefore building larger waves (Deacon, 1968) (Fig. 1). These larger waves are sought-after by surfers throughout the world, but the associated strength and direction of wave-driven currents in the surf zone can influence the surfability of a break. Significantly strong currents flowing downdrift along the shoreline do not allow a paddling surfer the opportunity to get to the “take-off” location of the break, or maintain position in the line-up.

Figure 1: The headland at Angourie Point, Australia with breaking waves. (Photo source: Tracks magazine)

2. SURFING HEADLANDS

Surfing headlands are shallow and exposed coastal features that provide a specific form of breaking wave allowing a board-rider to ride on the unbroken wave face. The form of breaking waves is affected by several factors, which includes not only the scale of the headland, shape of the seabed, wave height and period (Dally, 1989; Sayce, 1997), but also the wind strength and direction (Button, 1991; Galloway *et al.,* 1989; Moffat and Nichol, 1989)(Fig. 2). Mead and Black (2001a, b), found that there are a variety of properties that put world-class surfing breaks in a category of their own, but it is the seabed shape that has the largest influence on the form of a breaking wave and therefore the quality of a surfing break.

Figure 2: Waves breaking in the lee of the headland at Pambula, Australia.

Refraction changes the direction of wave propagation causing wave crests to align more parallel with the seabed contours (Komar, 1998). This is important for surfing because it alters the peel angle. The closer aligned the crest lines and the isobaths become, the greater velocity the surfer must attain to successfully ride the wave (Walker *et al*., 1972). On a headland refraction can alter the waves and have a significant affect on the peel angle and type of surfing waves generated. The orientation of the headland in relation to the pre-dominant swell direction can cause significant refraction to occur as waves bend into the headland. The peel angle and surfability for a specific swell can therefore change depending on the direction of this swell (Fig. 3). Refraction is therefore considered the dominant factor controlling surfing wave quality at a headland (Hutt, 1997).

Figure 3: Waves refracting around a headland at Rincon, California to create high-quality surfing waves.

As waves pass into shallow water they slow down, increase in wave height and decrease in wavelength (Komar, 1998). As a wave approaches a headland, the part of the wave closest to the land slows more rapidly than the other part that is in deeper water. This causes the wave to bend. Because refraction begins to occur with the water depth is around 0.5 the wave length (Komar, 1998), the amount that waves bend into the coast depends on the wave period. Long period swells bend significantly, compared to short period waves such as small chop, which do not 'feel' the bottom until relatively shallow water and therefore cannot bend into large embayments (Mead, 2000). Point breaks at headlands can therefore have excellent quality surf compared to the rest of the coast, as only the low frequency swell refracts around the headland to create the breaking waves. Refraction also causes the wave height to decrease, as the more the waves refract around a headland the more they decrease in height (Komar, 1998). The 'headland effect' (Mead and Black, 2001b) is demonstrated at surf breaks such as large headland at Shipwreck Bay (Ahipara), with either a very large swell or a very long period swell required to bend around the headland and create surfing waves (Figs. 4 and 5) – a combination of both large wave heights and long period swell produces the best waves.

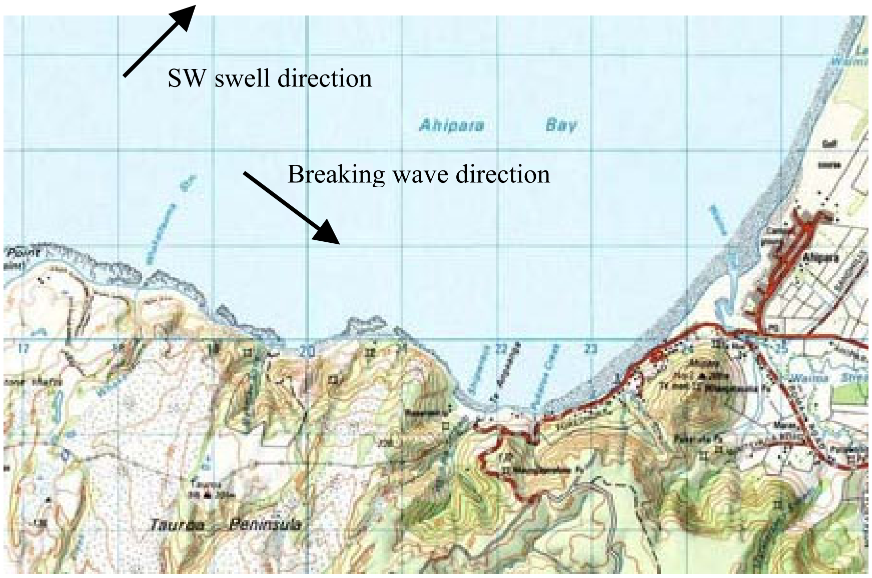


Figure 4: Map of Shipwreck Bay, Ahipara showing the swell and wave directions and the amount of refraction that occurs for waves to break along the headland.

Figure 5: Surfing waves breaking at Shipwreck bay, Ahipara.

3. CURRENTS INFLUENCE ON SURFING BREAKS

Strong currents are something that surfers have to deal with almost every time they paddle out. Most often, the current are wave-driven, but tidal jets near river and estuary bar surfing breaks, and even large oceanic currents can impact on the surfability of a surfing breaks. This section gives examples of the variety of different current surfers have to deal with.

It is well documented that when waves approach a shore at an oblique angle, a shore-parallel current is generated as waves break in the near-shore zone, transporting sediment along the coast (Fredscoe & Diegard, 1992; Komar, 1998). Headlands can be classified as mis-aligned sections of the coast, where the higher angle generates strong wave-driven currents. Currents at surfing headlands have been previously studied in relation to sediment transport and dynamics of the adjoining coast, and have a major influence on the seabed stability of the headland (eg: Kirra Point, Greenmount, Noosa Heads – all in Queensland, Australia).

Currents also have an influence on the surfability of a surf-break at a headland by limiting access to the surf and the ability to get into and maintain position in the line-up. Black and Symonds (2001) found that strong wave-driven currents occur over reefs when the reef is: (i) narrow; (ii) detached; (iii) fully submerged; and (iv) smooth with low frictional resistance. At a headland the wave-driven currents flow along the headland and make it very difficult to surf in large conditions.

However, currents can work in the favour of the surfer when flowing out towards the “take-off” zone, as seen at surf breaks near harbours and rivermouths, with an ebb tide creating an easy paddle out in the deep channel. This is demonstrated at the Whangamata bar on the Coromandel Pennisula in New Zealand, where surfers are taken out to sea from the “take-off” zone on an outgoing tide. However, the strong out-flowing current also means surfers must continually paddle against the flow to stay in the “take-off” area of the break. At Omaha bar, north of Auckland, the reverse occurs where surfers must continually paddle wide from the initial break-point, as currents push over the bar taking surfers too far inside the breaking wave zone, making it difficult to catch waves. The current can also increase the shoaling of the wave as it breaks, with the outgoing flow significantly "sucking" the wave face, possibly creating a "tubing" wave. This is seen in places such as Whangapoa on Great Barrier Island, New Zealand.

On the Gold Coast of Australia, a number of world-class point breaks exist at the sub-zeta headlands north of the large Point Danger headland (Fig. 6). These breaks include Greenmount, Kirra Point (Fig. 7) and Burleigh Heads. During medium to large swell events at these surfing breaks, a significant northward current flows in the direction of the waves that is very difficult to paddle against. This current extends significantly wide of the surf zone and requires surfers to constantly paddle in order to maintain position in the line-up. Jumping from the rocks up-coast is often the only means of getting out to surf the break.

Figure 6: Aerial view of Point Danger to Kirra Point breakwater at the top of the picture, Gold Coast, Australia.

Figure 7: Kirra Point, breaking along the headland from the groyne. (Photo source: Tracks Magazine).

Bathymetric surveys and analysis by Black *et al.* (1998) showed that Kirra and Burleigh Heads have steep seabed gradients down to depths of ~6 m formed by large sand banks running parallel to the headland. These linear sand banks are probably "break point" bars formed by the interaction of wave breaking and the stream-like rip currents that travel down these headlands when a large swell is running. The seabed gradient reduces below 6 m and could be part of the reason for the wide streaming current down the headland. The surfing headlands are also of a small scale when compared to the overall size of the coastline in the area.

In comparison the world famous break at Desert Point in Lombok, Indonesia (Fig. 8) has a very large wave-driven current in the breaking wave zone, but seawards of this a significant counter-current exists flowing back out to sea (J. Frazerhurst pers comm.). This current makes paddling “out the back” very easy, but unless a wave is caught surfers can be taken past the “take-off” point and struggle to get back to the breaking wave zone. This current may be mostly due to the flow through the Lombok straight that runs at a minimum of 7-8 knots.

Figure 8: Desert Point in Lombok, Indonesia rated as the best wave in the world by Tracks surfing magazine. (Photo source: Tracks Magazine).

3.0 SURFING ON THE RAGLAN HEADLAND

Raglan is considered a world class surfing wave and is known as one of New Zealand’s most consistent breaking waves (Bhana, 1988) (Fig. 9). It is located on the west coast of the country, and is comprised of seven surf breaks, with each having its own distinctive form of breaking wave (Fig. 10). The large scale of the Raglan headland (13 km from Ruapuke Beach to the Raglan harbour entrance) creates an environment where not only is there a variety of surf breaks, but each represents a compartmentalization of the shoreline along the headland. This creates variability in wave and current characteristics depending on the orientation and bathymetry at different locations.

Figure 9: Waves breaking along the Indicators surf break at Raglan (Source: ragtimeblue.co.nz).

The breaks are comprised of various components and wave characteristics (ie: different peel angles) as described by Mead and Black (2001a, b) and Scarfe (2002). At the tip of the headland is Outsides with wave characteristics that are moderate to very steep, hollow with moderate to fast sections. Further down the down the headland is Indicators, the predominant study site of field experiments presented here, which has moderate to steep waves that are steep to hollow with fast sections. The Valley breaks inside Indicators and has steep to very steep waves that are hollow and break with fast to very fast sections. Whale Bay is the slowest of the surfing waves with a moderate peel angle and moderate to steep waves. The next break is Boneyards, which is also slower with less power than the other Raglan breaks. Between Boneyards and Manu Bay is the Ledge, which can produce the hollowest and fastest tubes on the headland when the conditions are right. The furthest break down the headland is Manu Bay, which produces moderate to steep waves with occasional short hollow and fast sections. It must be noted that these are general descriptions, and under swell conditions different from the predominant SW swell, and during different phases of the tide, all breaks can produce significantly different waves than those described above.

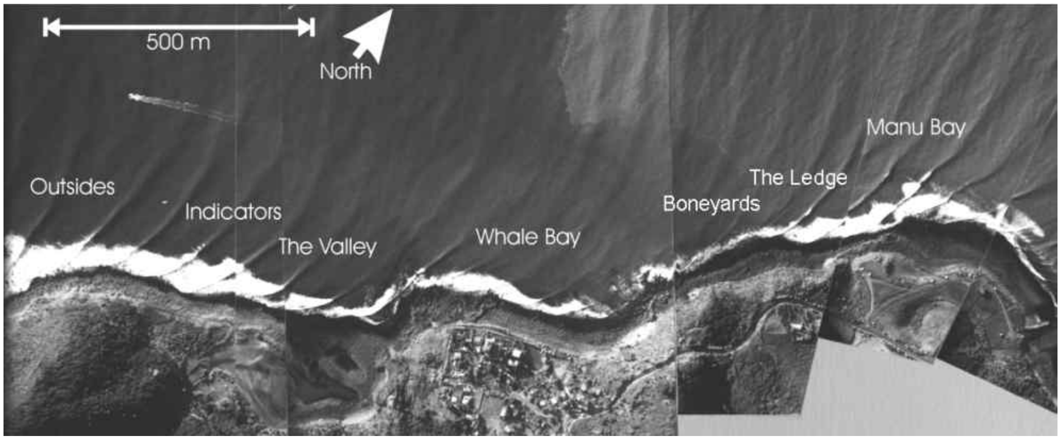


Figure 10: Aerial photo of the Raglan Surfing Breaks (Hutt, *et al.,* 2001)

3. RAGLAN FIELD EXPERIMENTS

A large multi-faceted field experiment was previously undertaken at Raglan in 1996. This research on the surfing headland, has led to a greater understanding of the bathymetry, wave refraction, breakpoint location and surfing characteristics in this environment (Hutt, 1997; Mead, 2000; Sayce, 1997; Sayce *et al.,* 1999). The latest field experiments have been conducted to measure current speed and direction, as well as sediment flux during moderate and large swell events at Raglan. Bottom mounted frames were deployed from a boat and anchored to the seabed with weights, for stability and to maintain their position in the surf-zone (Fig. 11). The frames were fitted with S4 current meters and programmed to record burst data at a set interval per hour. The retrieved data was analysed in the Matlab programme tseries, providing burst-averaged data over the deployment period.

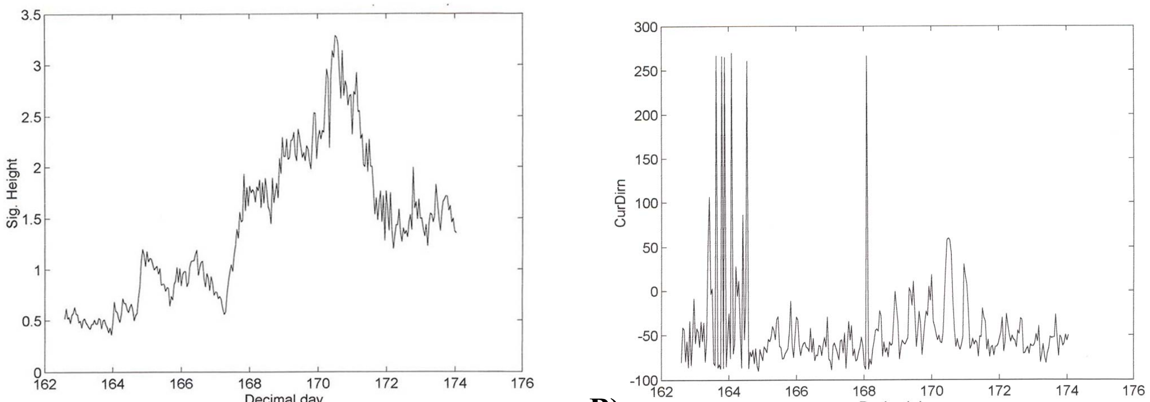
Figure 11: S4 current meter mounted on a frame ready for deployment in the surf zone.

Observations were also made of surfers attempting to paddle through the breaking-wave zone, confirming the strength of the wave-driven currents with surfers being swept rapidly down the headland for hundreds of metres. In large swells where the waves break in a pattern of sets, the lull period provides the opportunity for surfers to have a chance of paddling through the surf zone. However, this is not the case when the waves break with a consistent and continuous period, providing no opportunity for access to the surf-break.

In some locations such as Rincon surf break in California the out-flowing creek halfway up the headland provides a better access point as waves can be attenuated in this zone. At Raglan, a site at the end of the Whale Bay reef where the waves are not sweeping down the headland, but rather breaking into the reef between compartments provides a similar opportunity. A build-up of a pressure gradient and less current velocity in this area can increase the chances of getting out to the breaking waves.

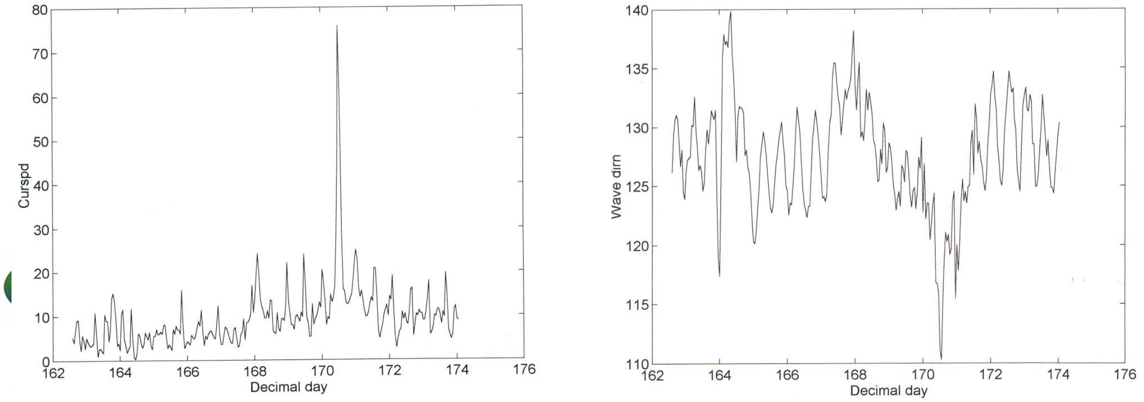
4. FIELDWORK RESULTS

During large swell conditions the results from the experiments at Raglan (Fig. 12), have shown strong currents in the inshore breaking wave zone with burst-averaged velocities attaining 0.8 ms^{-1}, and maximum bed orbital velocities of up to 2.0 ms^{-1} (Phillips *et al.,* 1999). The currents were directed down the headland in an easterly direction (50^0) and increased dramatically to the maximum value, as swell size peaked at 3.25 m. The combination of increased swell size and a dropping tide, meant the current direction at the headland decreased to 110^0 as the waves swept straighter down the headland.



A)

B)



C) **D)**

Figure 12: Graphs of data from field experiments A) Wave height (m); B) Current direction (degrees); C) Current speed (cms^{-1}); D) and Wave direction (degrees).

Interestingly, Phillips *et al.,* (1999) found that further offshore the currents have been found to flow in a re-circulating gyre back up the headland. These currents are significantly lower in velocity than the inshore flow, but can allow surfers an easier paddle back to the "take-off" point, although novice surfers have been known to experience difficulties being taken out to sea. Obviously surfers must first cross the fast flowing inshore current in the breaking wave zone, if this out-flowing conveyor is to have any advantage in surfing the break. As the size of the surf increases, the strength and width of the inshore wave-driven current also increases making surfing the site more difficult, if not impossible in 4-5 m swell.

5. ARTIFICIAL SURFING REEFS

Artificial surfing reefs (ASR's) exhibit many of the characteristics that generate strong wave-driven currents that could adversely affect surfing conditions at the break, i.e. they are (i) narrow; (ii) detached; (iii) fully submerged; and (iv) smooth with low frictional resistance (Symonds and Black, 2001). Design of artificial reefs need to consider the impacts of these currents if surfing amenity is to have optimum enhancement. Black and Mead (2001), describes the two types of offshore reef as "dissipators" and "rotators", working with nature by modifying the natural wave transformation processes to alter nearshore currents and obviate coastal erosion processes. The reefs act to break the waves and protect the coast by reducing wave energy in the lee of the structure, whilst also rotating waves to reduce the orientation angle, resulting in lower inshore wave-driven currents and therefore less longshore sediment transport. The reduced inshore currents also provide surfers with the opportunity to get to the take-off point of the break, increasing the surfability of the reef.

The Narrowneck surfing reef on the Gold Coast, Australia, is essentially a submerged headland, i.e. the reef contours are almost perpendicular to the natural seabed contours (Fig. 13). This orientation was required due to the large depth in which the reef is located (10.5 m deep on the offshore toe of the reef) in order to compensate for the large amount of refraction that occurs as the waves bend up on to the reef. If the reef had been designed as originally suggested, with reef contours at around 45° to the seabed contours (Fig. 14), refraction would have reduced wave peel angles so as to make them so small that the waves would break too fast to be surfable (Mead and Black, 2001b; Mead, these proceedings).

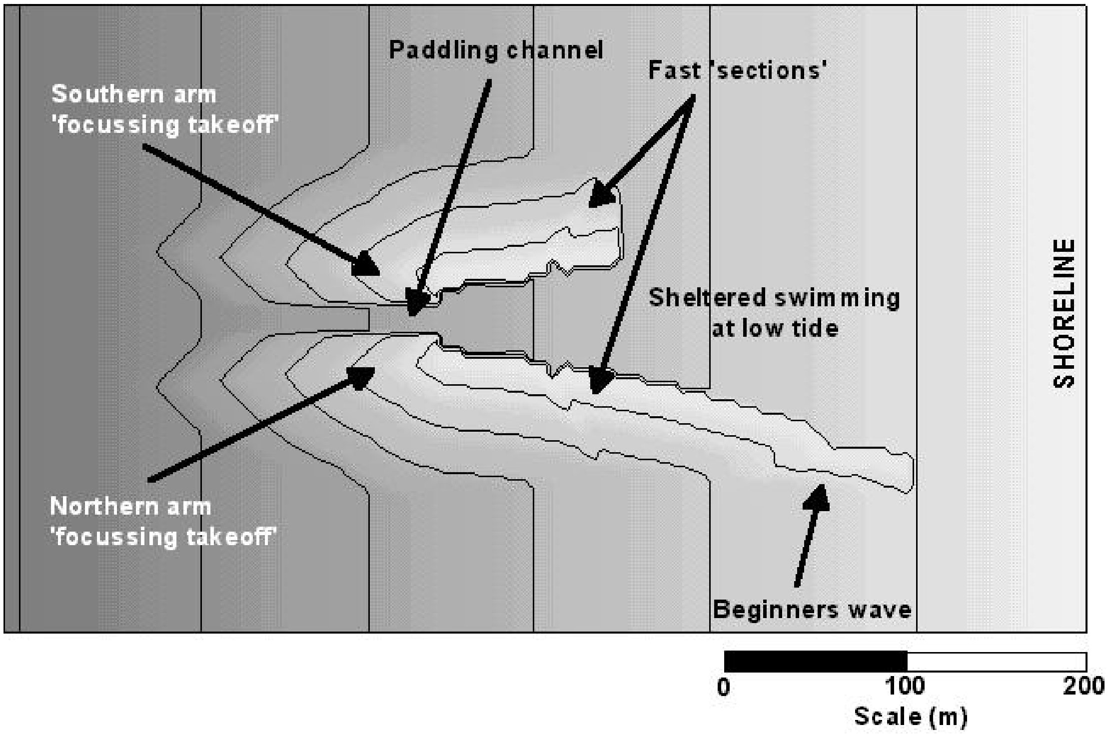


Figure 13: Narrowneck Reef.

Black (2001) identified a weakness in the Narrowneck reef design as being the strong wave-driven currents generated over the reef crest. The shoreward running currents in a 3-4 m swell, were predicted by Symonds and Black (2001) to exceed 1-1.5 ms^{-1}. These currents could sweep surfers caught in the breaking waves over the crest and into the shore. A design feature of the Narrowneck surfing reef to help compensate for this is the paddling channel between the two arms of the reef (Fig. 13), which allows surfers access to the break during moderate and large wave conditions (Black and Mead, 2001b). Even though wave-driven currents are directed inshore on the outer sides of the reef, the current is reversed through the paddling channel, aiding paddling out through the channel. In addition, shoreward of the reef, a ‘quiet zone’ provides sheltered paddling from the beach (Fig. 13).

The design of the Lyall Bay ASR in Wellington, New Zealand, does not incorporate a paddling channel (Fig. 15). This was due to budget constraints that would not allow the construction of two separate reef arms. The surfability of the reef could be enhanced by the incorporation of a paddling channel, especially during large swell conditions, when access to the take-off point could prove difficult.

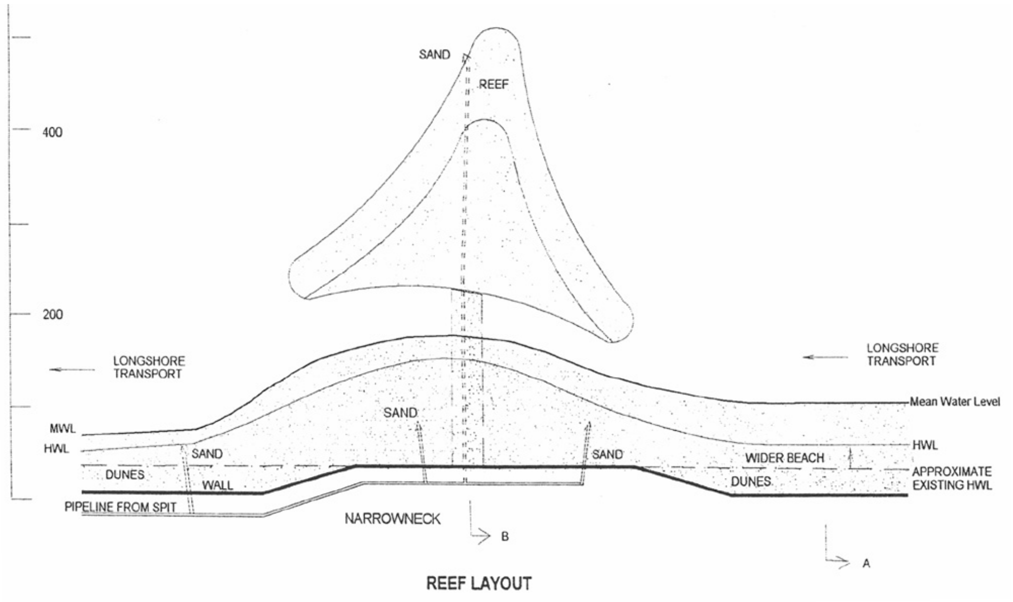


Figure 14. Early concept design of the Narrowneck surfing reef (Jackson et al., 1997).

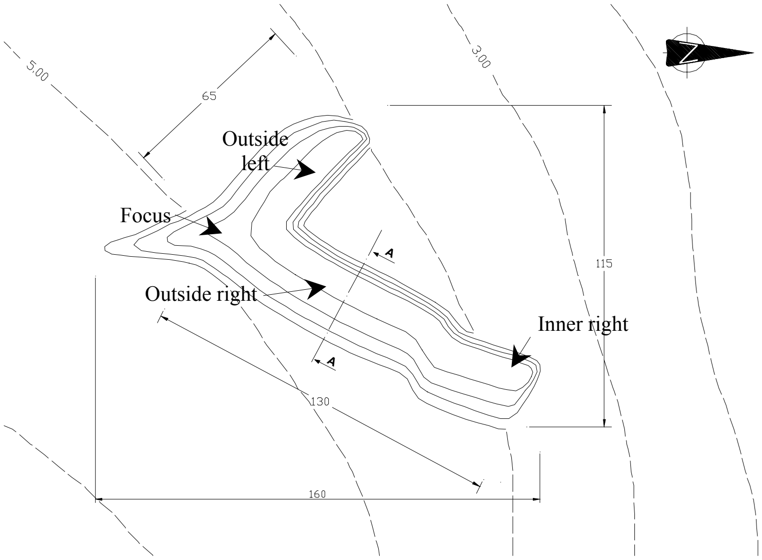


Figure 15. The final design of Lyall Bay Reef. (From Mead *et al*., 2003)

5. DISCUSSION

Headlands in small to moderate surf conditions can be classified as relatively easy to access when compared to beaches with similar surf conditions. Surfers must paddle through the breaker zone on a beach, whilst they must only get through a much narrower zone on a headland. However, this is not the case when large surf conditions prevail producing strong wave-driven currents in the surf-zone that significantly decreases the surfability of a break. This is due to the increased velocity of the wave-driven currents as the surf size becomes larger. Headlands are essentially mis-aligned sections of the coast, where the higher oblique angle generates strong wave-driven currents, when compared to a coastline in equilibrium with the dominant swell direction where the longshore flows are insignificant.

At some headlands where strong ebb-tidal outflow is found such as Whangamata bar, Coromandel Pennisula and Whangapoa on Great Barrier Island, New Zealand, the current assists surfers in not only getting to the take-off point but in creating barreling waves in this zone. However, difficulties can be experienced with continual paddling required to stay in position in the line-up, but this far outweighs having to watch perfect surf if no access can be obtained. Indeed, currents will always be something that surfers have to contend with, since they are an integral part of the surf zone.

The field experiments provided data for a 3 m swell at the Raglan headland. This data supported visual observations of surfers attempting to paddle out at the break, who were washed rapidly down the headland in strong currents. The data did, however, show a counter current further offshore that rotates back up the headland (Phillips *et al.,* 1999), but this current does not significantly increase the surfability as surfers must first paddle through the surf-zone to get to this area. On some natural headlands the morphology and bathymetry can allow greater surfability, such as a change in orientation or a deeper zone where the waves attenuate and currents decrease in velocity. The out-flowing creek at Rincon, California, is a classic example of this scenario. The scale of the headland is therefore important, as large scale headlands may provide the variability in coastline needed for different breaks with a mixture of peel angles and wave characteristics.

In the design of artificial surfing reefs the surfability of the break due to wave-driven currents must be considered if the amenity is to be maximized, especially during large surf conditions. Black (2001) described a limitation in the Gold Coast reef at Narrowneck, from wave-driven currents flowing over the reef and pushing surfers into the lagoon. However the reef does include a paddling channel between the two arms of the reef allowing better access to the take-off point in larger surf conditions by reversing the current direction. Future designs of artificial reefs should consider the impacts of currents on surfability as an integral factor, especially if big wave surfing is to be a component specified for the reef by the client. This has certain attractions to sponsors who may be interested in contributing funding to the project. However, features such as a paddling channel need to be considered, and may limit the ability to include greater surfability in the design of the reef.

6. CONCLUSION

Surfing headlands are shallow and exposed coastal features that provide long peeling waves allowing a board-rider to ride on the unbroken wave face. The seabed shape and refraction of the waves in relation to depth contours, is the greatest influence on the quality of the surf break, although due to headlands oblique orientation to the waves, strong wave-driven currents are often present. The large scale and orientation of the Raglan headland allows only the low frequency swells to refract around the headland to create surfing waves, a feature that makes headland breaks particularly sought after by surfers since waves will be ‘cleaner’ on headlands than on other parts of the coast. The large size of the Raglan headland also creates seven surf breaks, with each having its own distinctive form of breaking wave (i.e: different peel angles and breaking intensity). Each represents a compartmentalization of the shoreline along the headland. This creates variability in wave and current characteristics depending on the orientation and bathymetry at different locations. This provides not only potential access points through the surf-zone (ie: smaller currents), but greater surfability in a range of conditions that is not possible on small scale headlands.

Headlands can be classified as mis-aligned sections of the coast, where the higher oblique angle of the shoreline generates large wave-driven currents. This is confirmed by measurements in the surf-zone that have shown strong wave-driven currents at the Raglan surfing headland, that make the break difficult if not impossible to surf in large swell conditions. In a 3 m swell, burst-averaged velocities attained 0.8 ms^{-1}, and maximum bed orbital velocities of 2.0 ms^{-1}. A rotating gyre at the headland provides a counter-current further offshore that flows back up the headland. This current does not, however, assist surfers when the swell is very large (4-5+ m), as the downstream current inshore is too strong to cross.

Observations from a variety of other surf breaks around the world, provides further evidence of the influence that currents in the surf zone can have on the surfability of a break. These can sometimes be positive influences with out-flowing currents providing an easier paddle out for surfers to the break-point. The consideration of currents and the effect on surfability of an artificial surf break should be a component that is considered in the overall design of a reef if the amenity value is to be maximized, especially during large swell events.

7. ACKNOWLEDGEMENTS

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