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Development of a framework for assessing effects of coastal engineering works on a surf break

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Abstract
Surf breaks, particularly those of high quality, are a limited resource and of great importance to the local and broader surfing community. They provide not only a recreational activity but a sense of identity to local surfers and can increase tourism by bringing travelling surfers to the area. While engineering works are not a preferred option within the active coastal zone, they are at times unavoidable. A framework has been developed to test the potential physical effects of engineering works on a surf break. This framework includes a baseline assessment of the surf beak based on field investigations, discussions with local surfers and various modelling approaches; an effects assessment which includes identification of the physical elements which define the use and enjoyment of the surf break; development of methods to quantitatively test the potential for adverse effects on each of these elements; and finally a risk assessment which includes the likelihood, consequence and overall level of effect. This paper presents this framework together with a case study of its use at Mangamaunu, north of Kaikōura on the north east of New Zealand's South Island.

Keywords: surf break, coastal structures, wave modelling, effects assessment

1. Introduction

On 14 November 2016, an earthquake comprising a complex sequence of ruptures with a combined magnitude of 7.8 occurred approximately 60 km south-west of the Kaikōura Township, on the east coast of the South Island. This resulted in uplift of the coastline by up to 3 m and numerous large slips which closed State Highway 1 and the Main North Rail line north and south of Kaikōura.

Large-scale engineering works were required to re-open the road and to improve its long-term resilience to storms and effects of climate change. As part of the improvement works, a shared pedestrian and cycle path along the seaward edge of the state highway was proposed extending 17 km from Okiwi Bay in the north to Mangamaunu in the south. At Mangamaunu Point (Figure 1), there is a narrow transport corridor where the state highway and main rail trunk line compete for space and the existing rail line is meters from the coastal edge in places. The close proximity of the rail to the coast would result in the shared path needing to extend onto the upper beach in two locations with some form of coastal protection being required to support and protect the path.

Mangamaunu is a right hand point break with waves peeling along a cobble and boulder seabed off Mangamaunu Point. The Point comprises an outer section which picks up more southerly swell but is of lesser quality and an inner section which works better on east to northeast swells (Figure 2). This results in waves with long walls and hollow sections peeling for up to 250 m.

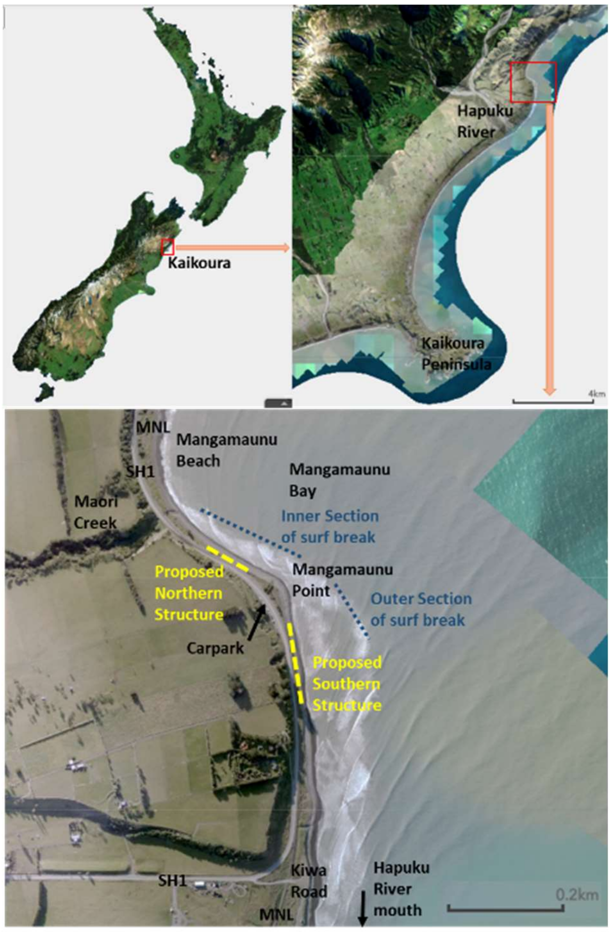

Figure 1 Location and features of Mangamaunu Point, surf break and proposed works

The surf break was also impacted by the November 2016 earthquake with the seabed and foreshore being raised by around 0.8 m. Based on local surfer feedback, this resulted in changes to the apparent water level and observed wave breaking characteristics.

Mangamaunu is recognised as a surf break of national significance within the New Zealand Coastal Policy Statement [2] and is very important to local surfers, iwi and the wider community. Consents granted for the coastal works required a baseline assessment characterising the surf break and the effects of the earthquake sequence, as well as an effects assessment to quantify and avoid adverse effects by the proposed works. The resulting assessment is described in detail [7] with methodologies and results summarised below.

Figure 2 Inside section of the Mangamaunu surf break (photo: Brent Proctor)

2. Framework development

While considerable literature exists characterising and evaluating surf breaks [1, 3, 6], no comprehensive methodology for assessing potential impacts of engineering works was available at the time of assessment.

A framework was therefore developed (Figure 3) to first characterise the existing environment and the way in which it is used. The potential effects of proposed works on that usage could then be evaluated using appropriate methodologies with results used to inform a risk assessment that could be fed into decision-making or design optimisation. The framework is described in detail below, with reference to how this was undertaken for the assessment at Mangamaunu.

3. Surf break characteristics

While the physical features of a surf break may be generally described using field data and modelling tools, detailed characterisation of a surf break requires incorporation of local knowledge of the surf break mechanisms; how the wave breaks, what conditions it works in, how it has changed over time and what is involved in surfing it. Each surfer views the surf break slightly differently depending on the board they ride, the conditions they enjoy and the part of the wave they tend to surf. It is therefore important that local knowledge is sought from a wide cross-section of the user community.

For Mangamaunu, interviews were undertaken with a cross-section of local surfers. These surfers described the surf break, the conditions it works in, how the earthquake has affected the break and finally key concerns with the proposed works. This local knowledge could then be combined with field data such as topography, bathymetry (Figure 4), sediment data, long-term wind, wave and water level hindcasts and detailed numerical wave-flow modelling [9] to develop a comprehensive description of the coastal processes and surf break mechanics.

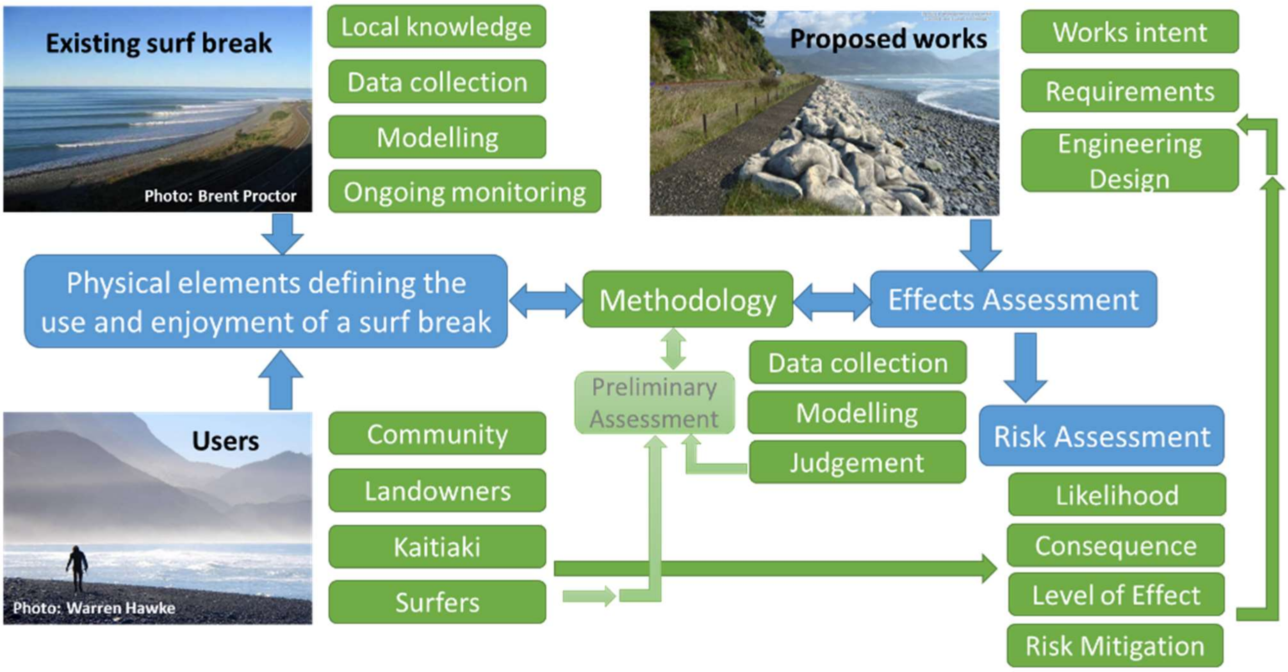

Figure 3 Framework utilised to characterise the surf break, and to assess effects and risk from proposed works

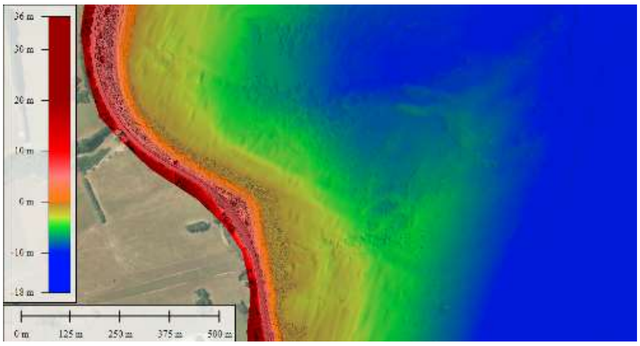

Figure 4 Topography and bathymetry of Mangamaunu Point showing a large offshore shoal and deeper water within the bay (m NZVD2016)

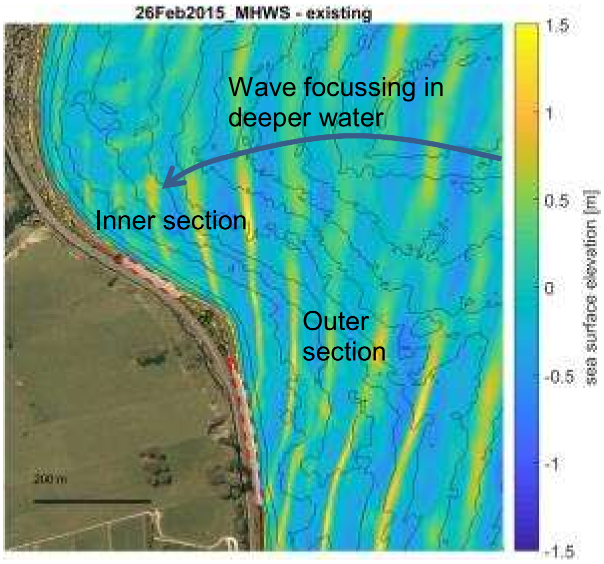

Figure 5 Example of incoming wave forms during a reported optimal condition

Local surfers reported that the outer section is surfable in most swell directions and tides, although it fades (decreases in size) towards the inside on south swells and sections (breaks in front) on east to north-east swells. The inner sections is generally regarded as the highest quality part of the surf break. South swell does not typically 'get in' to the inner section, being partially blocked by the outer section. As the swell turns more east a wider section begins to form approaching from the northeast. This wave breaks and peels along the point close to the rock and can be fast and hollow. This section is best on mid to high tides.

Based on surfer interviews, examination of field data and nearshore modelling [9], It was found that the seabed to the south of the point gently slopes towards the southeast, acting as a 'ramp' [4] which results in waves shoaling and becoming aligned to the east-southeast contours, but relatively little three-dimensional change in the wave form. The outer section of the point acts as a wedge, with waves breaking and peeling towards the north. However, a submarine spit extends into Mangamaunu Bay as the shoreline moves away towards the northwest and the bay opens up. This relatively shallower feature acts as a focus, with waves refracting around the northern end of the shallow feature and moving more rapidly within the deeper water of the bay. This results in waves arriving at the inner section of Mangamaunu from a more northeast direction (Figure 5) as described by local surfers. These waves are more aligned or 'square' on to the contours and the seabed slopes more steeply from this direction. This results in a faster and harder breaking wave than would otherwise occur with waves peeling down the point.

3.1 Effect of earthquake

Complicating the picture at Mangamaunu is the effects of the Nov 2016 Earthquake which uplifted the seabed and foreshore by around 0.8m (Figure 6). This uplift meant that high tide now appears as mid-tide had previously and low tide now appears extremely low. This affected the surf break but was not reported as a uniform shift in the wave regime as a result of the changed relative water level. Certain conditions were reported to be now improved while the quality was reduced during others. In general the consensus was that under previously ideal easterly conditions the wave had more of a section, or was split in two, but the wave is now working more often in a wider range of conditions.

Figure 6 Example of coastal uplift and exposed nearshore seabed at Mangamaunu (Photo: Kevin Shaw)

4. Physical elements defining usage and enjoyment of a surf break

In order to robustly assess the potential for an activity to affect usage of a surf break, the physical elements which defined the use and enjoyment of the surf break must first be identified. Based on the potential for the proposed physical works to affect these elements, appropriate methodologies to quantify effects can then be developed.

The elements should encompass all aspects of using a break; from checking, accessing, surfing and enjoying the area. These elements all contribute to the experience and must therefore be considered. However, to allow consideration of the potential effects, the individual elements must be defined.

Physical elements contributing to the use and enjoyment of the Mangamaunu surf break have been set out in Figure 7. These have been based on a combination of those provided in literature (i.e. [1, 3, 4]), the authors' experience and knowledge of surf breaks and feedback from local surfers.

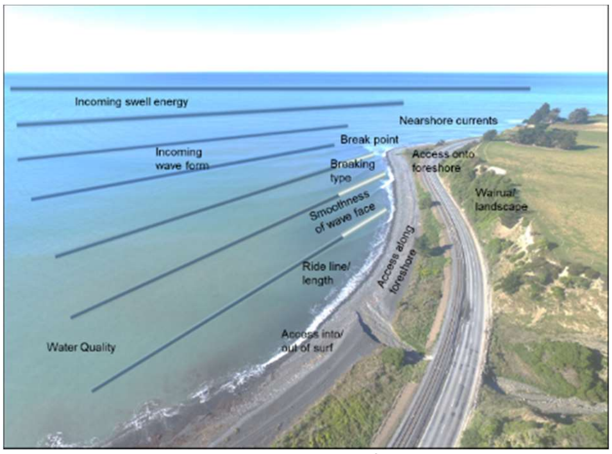

Figure 7 Physical elements defining the use and enjoyment of a surf break

5. Proposed works

Physical works generally begin with an intent – they are intended to provide protection, access, amenity or other usage. They are governed by a set of requirements to achieve the intent and designed to these requirements. Design is often an iterative process with preliminary design refined to better achieve intent or minimise adverse effect.

At Mangamaunu, the proposed works included either a revetment or a piled structure extending along two sections of coast; 300 m to the south of Mangamaunu Point and 170 m to the north.

Figure 8 Landscape visualisation of one form of the engineering works proposed to support the shared path

The works would intersect the underlying cobble/boulder substrate below the ephemeral gravels/sands at around RL 1.2 m along the southern revetment (mean high water spring water level being ~RL0.64 m) with a toe embedded down to around RL 0 m, and at around RL 1.6 m along the northern revetment with a toe embedded down to around RL 0.5 m. The intersection with the sand and gravel beach which overlies the cobble/boulder substrate will likely be higher depending on beach volumes at the time but, based on June 2018 LiDAR, would occur at around RL 2 m and RL 2.8 m respectively (1.35 and 2.15 m above MHWS level). A landscape visualisation of the southern revetment is shown in Figure 8.

6. Effects assessment

In order to develop methodologies that can be used to test the likelihood for, and consequences of the proposed works on the surf break, a preliminary assessment must be undertaken of the ways in which the physical elements could be affected. This is undertaken using a combination of expert judgement and local knowledge which can include key concerns. From this, ways in which physical elements may be affected are identified and a methodology to test each is defined.

For Mangamaunu, changes to the offshore conditions as a result of the proposed works are not likely as the works are confined to the backshore. However, the earthquake has changed the offshore conditions, therefore wave modelling under pre- and post-quake was undertaken to quantify these changes. Key concerns of local users were related to the potential for increased reflections (defined by the smoothness of the wave face) and changes in access. The proposed methodology for assessment of changes to each element is presented within Table 1.

The assessment included 1D physical modelling to identify complex, small-scale effects such as wave-structure interactions [7], 2D numerical modelling to identify changes in waves and currents [9], and empirical modelling and judgement to assess changes in access. Effects on the look and feel of the area (wairua) was not assessed specifically but should be considered in a wider assessment.

Results found no change in incoming wave energy (the swell corridor), incoming wave form, the location of breaking waves, ride length or line. Some potential effect on wave smoothness in the outer section of the break was found with an increase in wave reflection from the southern revetment possible. These reflections would manifest as smaller waveforms travelling offshore and likely already occur during high tide conditions. The changes during surfable conditions were found to be negligible in the physical modelling (±1% change compared to existing reflection) but more notable changes were identified in numerical modelling (Figure 9). This modelling found that reflected wave height during optimal conditions at high tide may increase from 0.29 - 0.38 m along the outside wave section, to 0.3 - 0.42 m, an increase of up to 0.06 m or around 6%. However, it should be noted that in a wide surf zone the reflected waves take some time to travel back offshore to the break point and therefore may be out of phase with set waves (i.e. the breaking set waves and reflected waves will not occur simultaneously). Effects on the wave smoothness within the inner section of the surf zone was found to be negligible compared to existing in both the physical and numerical modelling.

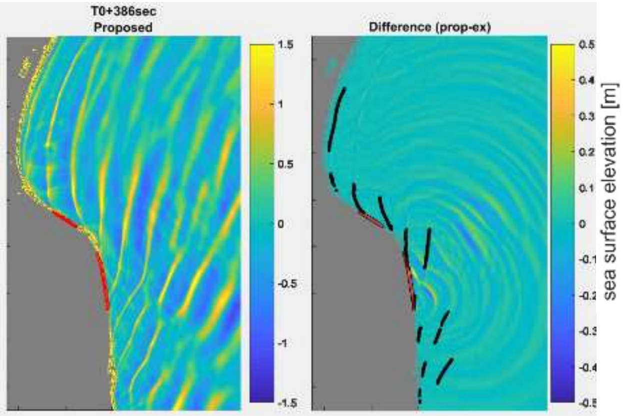

Figure 9 Snap shot of sea surface elevation during an optimal event including the proposed works (left) and the difference (right) with breaking portions of wave forms identified in black

No changes were found in the seabed levels or form in front of the beach and structure during physical model testing. Small changes were identified in surf zone currents (Figure 10), although these are unlikely to be noticeable to surfers or affect sediment transport. Overall, much more significant changes in currents and nearshore wave heights have arisen as a result of the November 2016 earthquake.

Some effect on access along the foreshore was identified with the proposed works footprint intruding into the swash zone during higher wave and water level conditions. However this, and the effects identified above, do not account for the potential for the beaches to further accrete in the short- to medium-term due to increased sediment supply from the Hapuku River due to increased volumes of alluvium, as well as uplift. If this occurs (or the sediment evident in September 2018 remains) then all effects will be substantially reduced with wave swash rarely reaching the shared path or any structures still required to protect the path.

7. Risk assessment

A risk assessment criteria was developed based on the NZTA coastal effects assessment guideline [5] and modified to include effect level based on standard RMA terms [8]. The criteria for likelihood, consequence and level of effect are set out in Tables 2, 3 and 4. While the level of effect is a function of likelihood and risk, it should be determined by a combination of local and expert judgement rather than matrix based rules.

8. Ongoing monitoring

Ongoing monitoring both before, during and after works provides a way of testing assumptions, and validating models and predictions. Monitoring can include physical aspects such as using camera systems to detect breaking position under a range of conditions or surveys to monitor beach changes or of user characteristics such as usage frequency, access and exit points and ride lines.

At Mangamaunu, ground-controlled imagery is being captured from two locations and processed (Figure 11), GPS ride data, topographic profile surveys, LiDAR and aerial imagery are being collected on an ongoing basis.

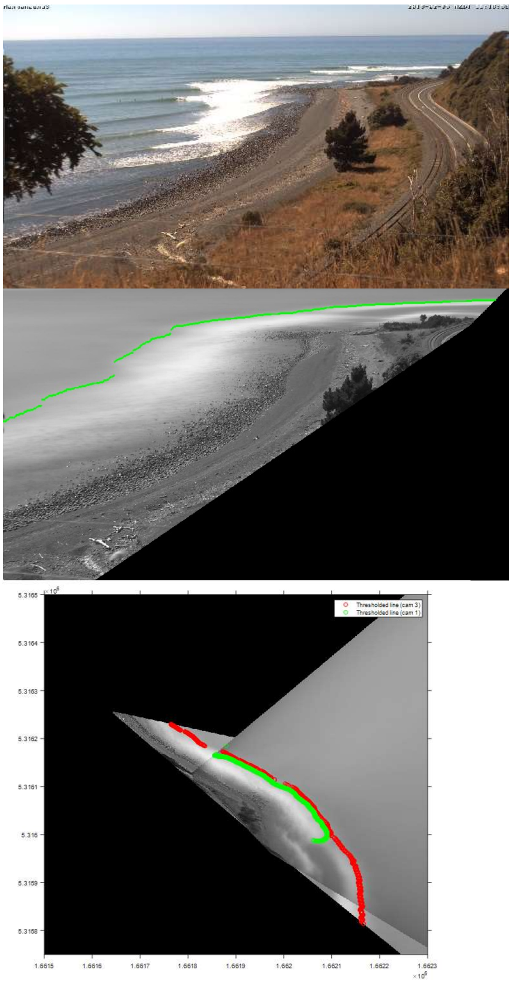

Figure 10 Example of a ground-controlled oblique image (top), time-averaged and breaking line defined (middle) and images from two cameras rectified and georeferenced (lower).

9. Summary

As a result of this study, a framework for undertaking robust, evidence-based effects and risk assessment for surf breaks has been developed. This framework is flexible and can be modified to suit particular environments or works. Underpinning this approach, however, is that the local community and users are actively engaged throughout the process including defining how the surf break works, what is of value, how this should be tested and what the results mean in terms of level of effect. For Mangamaunu, as a result of the effects assessment and likelihood of various effects outlined in Table 5, a decision was made by the Transport Agency not to progress the shared use path under the current consents. Monitoring data is being collected including of beach levels, widths and volumes and of the surf break using cameras and GPS watches.

10. Acknowledgements

The authors acknowledge the NZ Transport Agency and KiwiRail for funding this work via the North Canterbury Transport Infrastructure Recovery (NCTIR) Alliance. NCTIR was set up by the NZ Government late December 2016 to restore the earthquake damaged infrastructure between Picton and Christchurch. NCTIR is an alliance partnership between the NZ Transport Agency, KiwiRail, Downer, Fulton Hogan, HEB and Higgins.

Several local surfers are thanked for their input and discussion on the existing surf break, changes since the earthquake and their concerns on the proposed works. Matt Moriarty is additionally thanked for his ongoing collection of ride data using a GPS surf watch. Patrick Knook, Lucy Whitelock-Bell and Jason Ng at Tonkin + Taylor are thanked for data analysis, Ben Blumberg and Indra Jayewardene at MHL for physical model testing and Sébastien Thiebaut at Metocean solutions for hindcasting.

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Table 1 Proposed methodology for assessing potential physical effects on the Mangamaunu surf break

Physical elements defining the use and enjoyment of a surf break	**Description and ways by which the surf break may be affected**	**Assessment methodology for Mangamaunu surf break**
Incoming swell energy	Controlled by swell corridor affecting energy reaching break. Can be affected by an offshore obstacle or change in seabed.	Wave hindcasting to determine dominant incoming wave directions. Wave modelling of pre-earthquake and existing conditions and with proposed works to determine difference in wave height reaching break.
Incoming wave form	Controlled by offshore and nearshore bathymetry prior to breaking. Can be affected by change in seabed.	Wave modelling using phase-resolving model to confirm incoming wave characteristics under a range of conditions for existing, pre-quake and proposed bathymetries.
Breaking point/type	Dependent on seabed morphology at breakpoint and offshore pre-conditioning (incoming wave form).	Assess potential for increased reflection due to proposed works during storm conditions to move seabed materials (cobbles/boulders) using 1D physical model.
Smoothness of face	Affected by reflected waves, prior breaking inducing decomposition, irregularity in seabed.	Assess potential for wave reflection under existing situation and with proposed works using 1D physical model[1] and in 2D using numerical model.
Ride line/length	Affected by structures or other objects in the ride line or change in bathymetry along ride line.	Use 1D physical model to identify potential for reflection and changes in seabed offshore of structure and 2D numerical model to identify changes in currents causing seabed changes and changes in break point.
Currents	Can be affected by surf zone circulation, modification of tidal flows.	Use 2D numerical model to identify changes in currents for pre-earthquake and existing conditions and with proposed works.
Access onto foreshore	Interruption of access between backshore (or arrival) and the foreshore (of surf access).	Identify post-works access locations compared to existing.
Access along foreshore	Interruption of safe access along the foreshore.	Assess structure geometry/location compared to depth of overlying sands/gravel beach and wave run up levels as % of total time.
Access into/out of surf	Interruption of safe access into/out of water.	Identify post-works entry/exit points compared to existing.

Physical elements defining the use and enjoyment of a surf break	Description and ways by which the surf break may be affected	Assessment methodology for Mangamaunu surf break
Water quality	Can be affected by discharges into the Coastal Marine Area.	Identify potential sources of contamination input.
Landscape (Wairua)	Factors affecting the look and feel of a surf break.	Assess using landscape visualisations and consultations (Korero)

Table 2 Example of Likelihood Criteria

None	Unlikely	Likely	Very likely
No reasonable likelihood of effect occurring	Effect could occur in the future or may only occur in rare conditions at present	Effect likely to occur in the future or occasionally at present (i.e. during particular conditions only)	Effect expected to occur frequently (i.e. during most surfable conditions)

Table 3 Examples of Consequence Criteria

None	Low	Medium	High
No effect	Effect does not affect use of surf break or has minor effect on lower quality surf break	Effect has a minor adverse effect on the use of a high quality surf break or moderate effect on lower quality surf break	Effect has a moderate adverse effect on the use of a high quality surf break or significant adverse effect on the use of a lower quality surf break

Table 4 Interpretation of assessed level of effect against standard RMA terms [8]

Level of Effect	Description
No effect	No effects on the surf break at all
Less than minor adverse effects	Effects on the surf break that are discernible day-to-day, but too small to adversely affect surf break value
Minor adverse effects	Adverse effects on the surf break that are noticeable but that will not cause any significant adverse impacts
More than minor adverse effects	Adverse effects on the surf break that are noticeable that may cause an adverse impact but could be potentially mitigated or remedied
Significant adverse effects that could be remedied or mitigated	An effect that is noticeable and will have a serious adverse impact on the surf break but could potentially be mitigated or remedied
Unacceptable adverse effects	Extensive adverse effects on the surf break that cannot be avoided, remedied or mitigated

Table 5 Risk assessment for the Mangamaunu surf break for a rock revetment option based on NZTA (2017) method

Description of effect		Risk assessment			Risk mitigation/ comment
		Likelihood	Consequence	Level of effect	
Incoming swell energy		None	None	No effect	None
Incoming wave form		None	None	No effect	None
Breaking point/type		None	None	No effect	None
Wave face	Outer section	Likely to Very likely (dependent on beach level)	Low	*To be determined in consultation with affected users*	*To be determined in consultation with affected users*
	Inner section	Unlikely at present sea levels	Medium (at future sea levels)		
Ride length/line		Unlikely	Low		
Surf zone currents		Likely	Low		
Access to/from foreshore		Unlikely – situation has not changed from existing	Low		
Access along foreshore		Likely – dependent on future beach levels	Low – Medium depending on beach levels		
Access into/out of surf		Unlikely – situation has not changed from existing	Low		