BASELINE STUDY OF THE RANGITATA RIVER MOUTH ENVIRONMENT

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1. Executive Summary

Context

The Rangitata River mouth environment is located along the Canterbury Bight, on the South Island of New Zealand. It is characterised by a mixed sand and gravel coastline, an requested a baseline of the geomorphic variability to be established. This report will be used by ECan to compare geomorphological changes as part of adaptive management approaches, to prepare for the impacts of climate change and increased water abstraction.

Research Question

What is the geomorphic variability of the Rangitata River mouth environment for future comparisons?

Methods

The methods for this report were based on secondary data analysis. These focused on:

- Satellite & aerial imagery (1937- 2020)
- Wave buoy data (1999 - 2019)
- River flow data (1979 - 2020)
- Beach profiles (1986 - 2019)

Key Findings

River outlet is dynamic but tends to be located northeast.

Southerly waves potentially cause northern migration of the outlet channel.

Easterly waves tend to cause short, dramatic changes to the shoreline.

High flow events cause significant change to the river outlet position and bar shape.

flow.

Beach profiles are highly dynamic with periods of erosion and accretion, as well as formation of a secondary channel.

Limitations

The key limitations were time constraints, irregularity, and gaps in the data, poor image resolution, human error, and difficulties corresponding data. Other limitations included the position of the wave buoy and river gauge and the unknown effect of the abstraction rate on the environment.

Further Research Suggestions

A deeper analysis into longshore drift, wind, tides, tectonic uplift, erosion rates, and sediment type and volume.

Installation of a webcam to get high quality daily data for a more consistent record.

Identify the potential impacts of climate change induced sea level rise, river flow, and wave effects on the environment.

3. Literature Review

3 controlling processes

Braided rivers that terminate at a wave-dominated mixed-sand and gravel coastline

are elongated lagoon environments and consist of non-estuarine bodies of water that are semi-enclosed by a barrier bar (Kirk, 1991; Kirk & Lauder, 2000; Paterson et al., 2001). Freshwater from the river enters the ocean via an outlet channel and seepage through the permeable bar (Hart, 2009).

ugh there

Canterbury. Specific studies on the Rakaia (McHaffie, 2010), Ashburton (Paterson et al.,

was completed 22-years ago (Todd, 1998). Therefore, further research of the RRME is required.

Fluvial processes are dominant influencers of geomorphology of large river mouths (Kirk, 1991). Understanding the influence these processes have is important due to management implications (Kirk, 1991). At least 7 m3/s of water has been diverted from the Rangitata River since 1945, which may affect the RRME through reduced flow (Hart & Bryan, 2008). Changes in river flow affect sediment supply and remobilisation (Masselink et al., 2014). Flooding events have the greatest impact on river mouth morphology (Kirk, 1991; Masselink et al., 2014). Rivers with higher base flows frequently breach the barrier bar due to flooding (Hart & Bryan, 2008). This breaching often changes outlet location and causes a sediment injection into the marine environment (Hart & Bryan, 2008). While low flow events have less

The dominant marine processes controlling river mouth morphology are waves and longshore currents (Hart & Bryan, 2008; Kirk, 1991). Waves remobilise and transport sediments on the shoreface (Hart, 2007; Todd, 1998). Wave approach can influence outlet channel location and angle, while wave height can influence channel width (Hart & Bryan, 2008; Kirk & Lauder, 2000; Measures, 2020).

(Pickrill & Mitchell, 1979). This generates a northern longshore current which has created the barrier bar at the RRME (Hart, 2009).

-term net erosional

per year (Eikaas & Hemmingsen, 2006; Gabites, 2005; Single, 2011). However, Hart (2009)

t be keeping pace with barrier erosion;

et al. 2019; Marfai et al. 2008; Ozturk & Sesli, 2015). This is beneficial as they have a wide range of data and may have better results.

4. Methodology

4.1 Aerial and Satellite Imagery

ArcMap was used to analyse and digitise the imagery. This allowed layers of images and feature classes to be compiled. Digitisation methods include creating line and polygon features. Polygons were used when analysing flood events, while lines were used in determining long-term trends. Furthermore, measuring tools in ArcMap and Google Earth Pro was used to establish measurements of features.

The satellite imagery used was sourced from Planet Labs, which provided images from 2016. The basemap used for georeferencing was a high-resolution Canterbury Maps image taken in February 2019. Historical aerial images were used to display long-term trends. These were sourced from Retrolens, which provided one image roughly every 10-years. Google Earth Pro images were also studied and had irregular images from 2006. These were higher quality than Planet Labs but often the dates did not correspond with notable events from river flow or wave data.

4.2 Beach Profiles

Beach profile surveys have been completed by Ea fsoa5]TJETQ0s.s92 reQ10(fsoa5]TJETQ0s.s92 reQ10(fsoa5

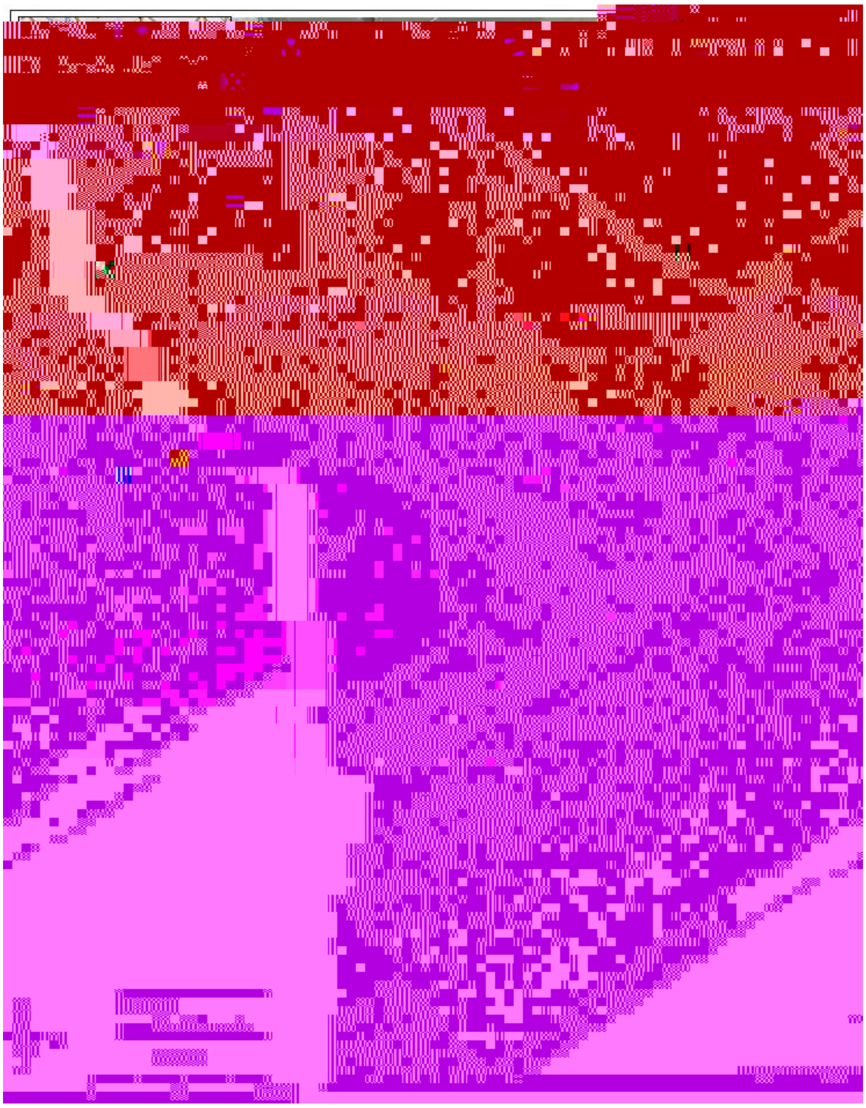

Figure 3. Map showing the location of the five beach profile sites. There 0(f)-30(f)-3 c(

4.3 Wave Data

Wave data was collected by ECan from a buoy 17 kilometers east of Banks Peninsula. The wave data record was from 1999 to 2019. ME was used to create tables, histograms, scatter plots, and bar charts to identify significant wave height and wave direction. Once geomorphic changes were identified through imagery, wave data for similar time periods was analysed.

4.4 River flow and rainfall

The river flow and rainfall data were supplied by ECan. The rainfall gauge records daily precipitation 120km upstream of the RRME. Data was recorded since 2010. River flow data was record

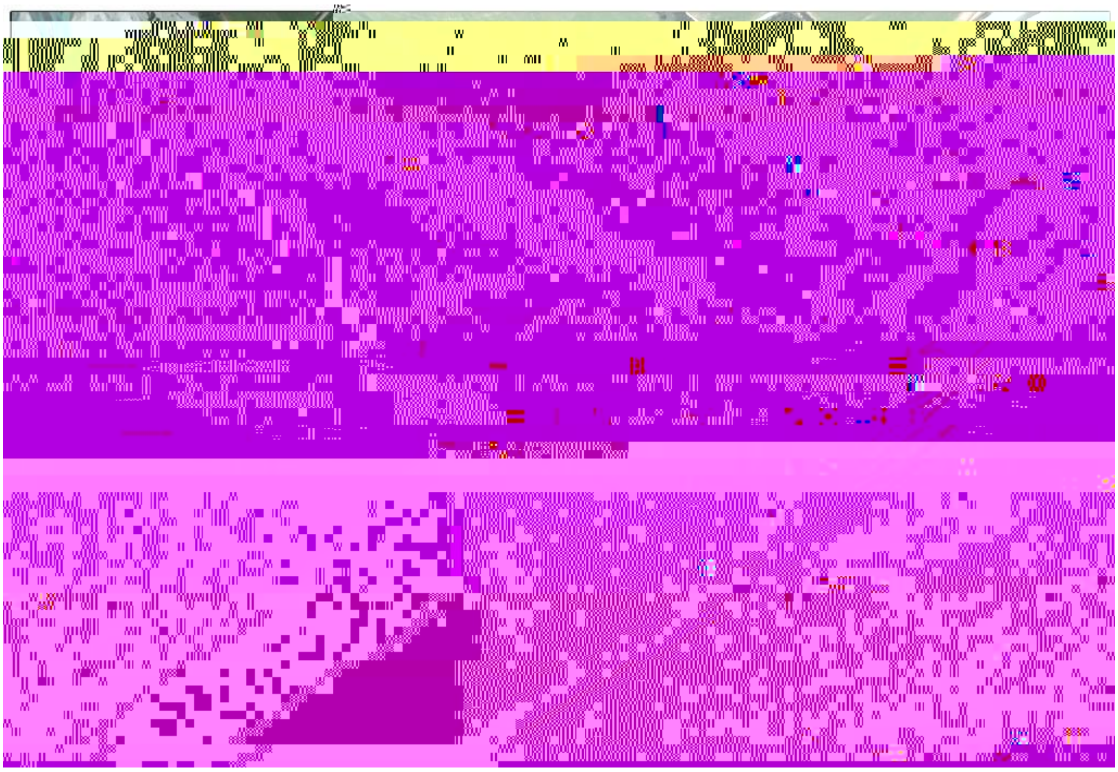

Figure 5. Map of the latest trends (2009-2019), with 2-year intervals between years. This was created in ArcMap, incorporating Google Earth and Planet Labs imagery. Bold lines represent the river outlet, while the dashed lines outline the shorelines. Basemap is February 2019 Latest Aerial Imagery from Canterbury Maps.

is decreasing in length but increasing in area over the last 80 years. During the last 10-years ined relatively stable, although the amount it extends past the northern huts forest line has receded by ~130m.

5.1.2 Beach Profiles

The southern beach profile envelope (RCN1548) (Apx. B1) shows that the site has been

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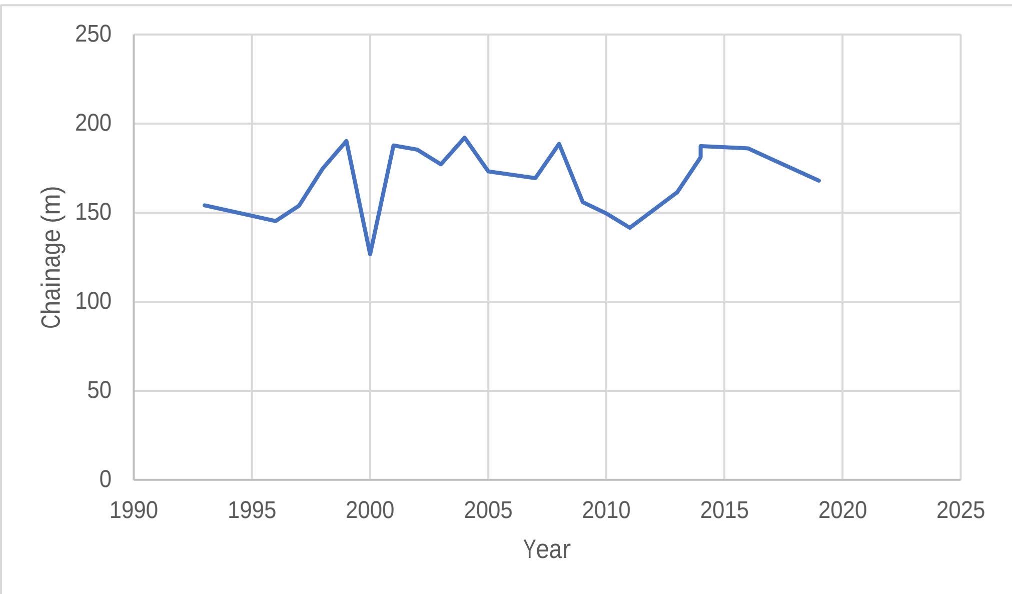

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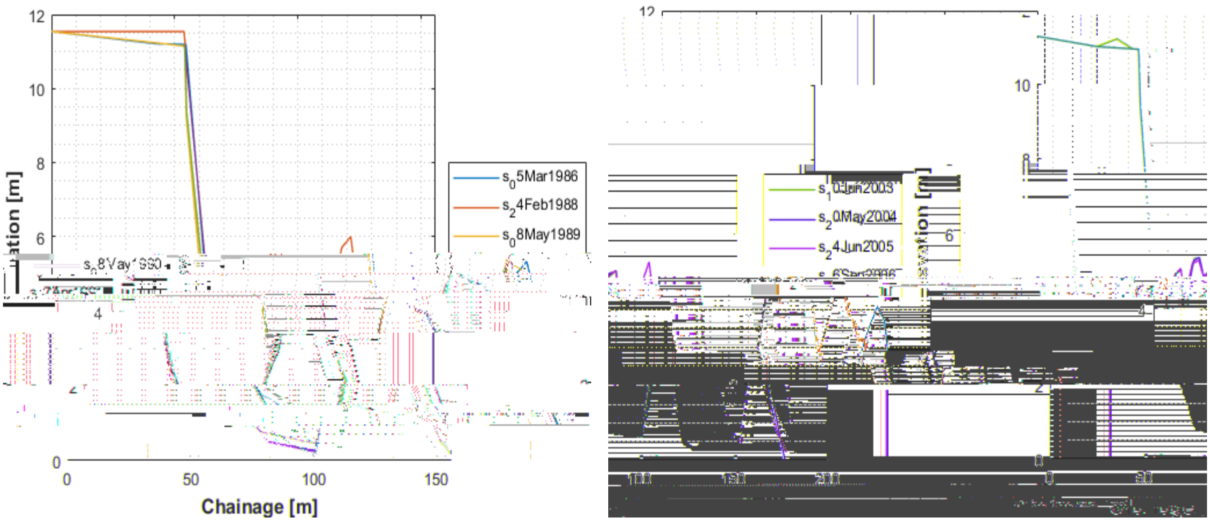
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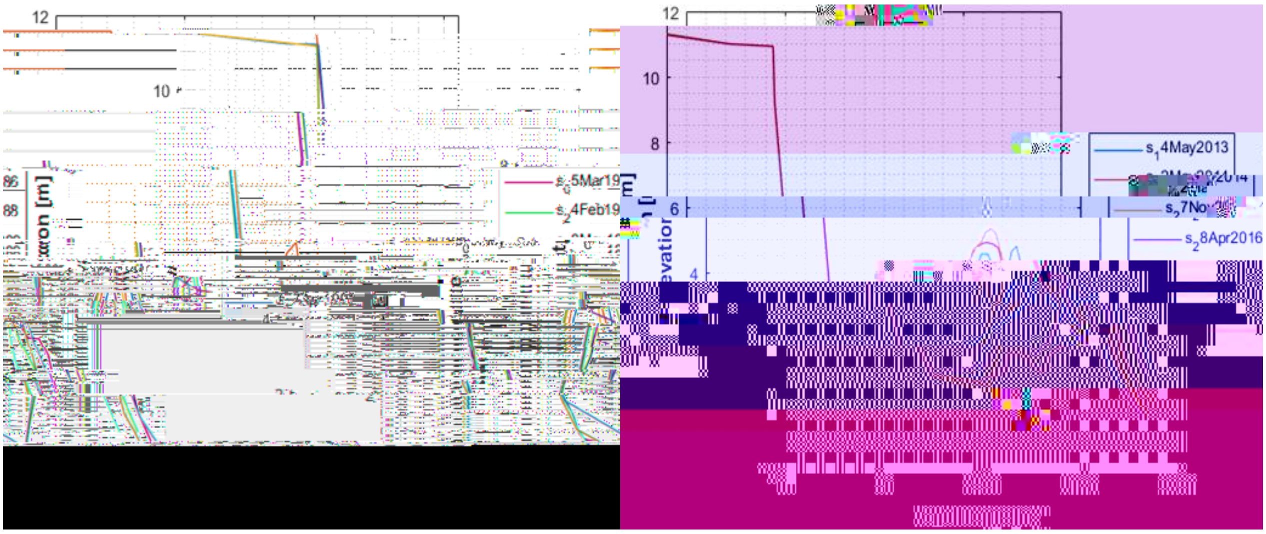

5.2 Short-term Trends

5.2.1 Imagery

Analysis of the five largest flood events from 2016-2020 showed similar trends. This time period was chosen because there was access to near-to daily imagery. The dominant morphological patterns were widening of the outlet channel, seaward movement of the bars near the outlet (Figure 15) and breaching of the barrier bar directly downstream of the main river flow (Figure 16) (see Apx. C for further detail).

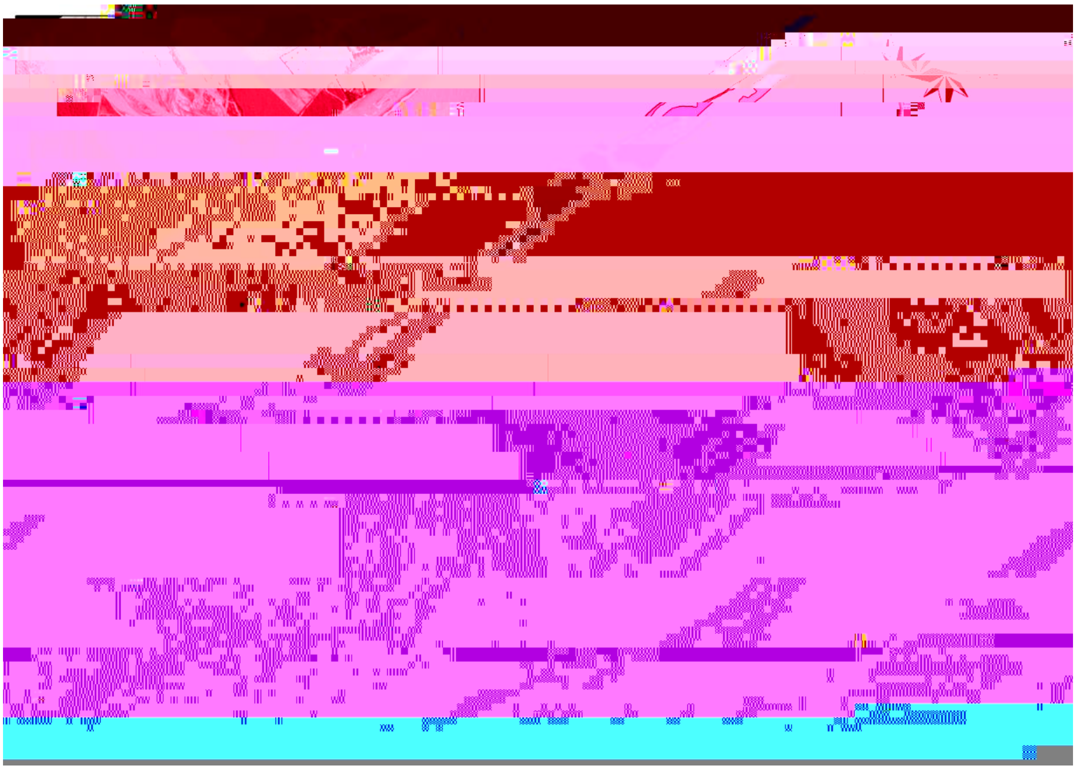

Figure 15. This sequence of images and polygons represents a flood event in November 2018 of 1847m3/s. The blue polygon represents where the bars were prior to the flood while the pink represents the bars during the flood. It is illustrated in the yellow polygon that after the flood the bars either side of the outlet moved seaward in a convex shape.

Figure 16. A sequence of prior, during and after a flood event in November 2018 of maximum 1847m3/s. The coloured polygons represent the bar features. Images sourced from Planet Labs.

Images since 2016 with corresponding river flows of less than 70m3/s indicates that the

17). There was no clear evidence to show full barrier bar closure.

Episodes of northern outlet migration were observed and commonly followed a flood event (Figure 18). Faster migration occurred initially after a flood as opposed to when the outlet

5.3 Analysed Controlling Factors

The dominant processes influencing RRME geomorphology are river flow and wave approach. Analysis of wave and river flow data showed that there were a range of long-term and short-term trends.

Wave analysis showed dominant wave direction is from the south (Apx. D). There was variation in wave heights with an average significant wave height of 1.5m (Apx. D). There were also occasions of high easterly waves, which may also control geomorphology at the RRME.

The river flow data shows no long-term trends for average high flows or average low flows, although a negative trend is illustrated in the annual average flow. The average monthly flow shows a seasonal trend with increased flow in the summer months, due to glacial melt and tropical cyclones (see Apx. E for further information). Flood events can reach as high as 2800cm3/s and can be associated with high rainfall (Apx. F shows associated graphs).

6. Discussion

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Models composed by Todd (1998) and Hart (2009) (Figure 2) are comparable to what was observed at the RRME (Figure 20). Links can be made with these morphological stages to both river flow and wave conditions. An increase in river flow can cause primary and secondary breaching of the barrier bar as the flow overtops the bars (Figures 18 &19)(Apx. F). While the northern longshore current is the probable driver for the northern outlet migration and elongation (Figure 21)(Apx. D3) (Hart, 2009; Kirk 1991; Todd 1998). Generally, the outlet is wider when it is in a southern or central position (Apx. G). This was associated with high flow events and recent breaches, while outlet narrowing and elongation with near-parallel alignment to the coastline was associated with low flows. This corresponds

closures (Figure 17) (Todd 1998). Although no bar closures were observed in this research, it is still a possibility.

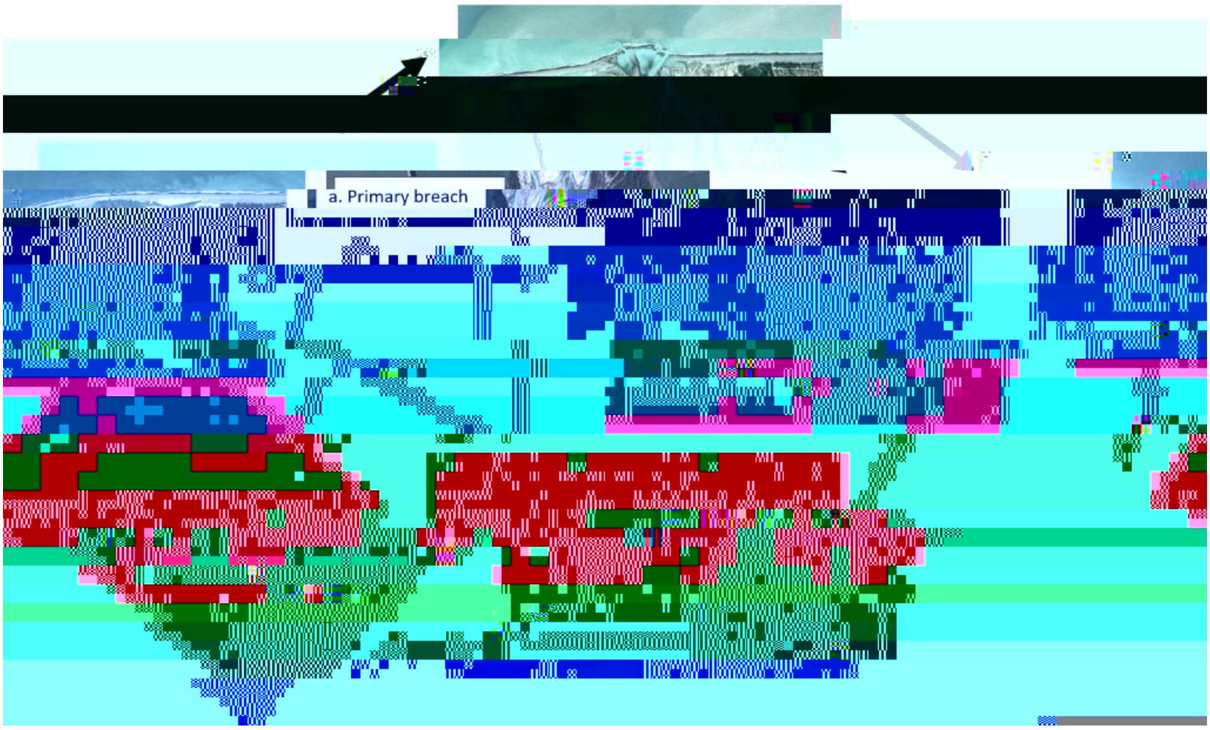

Figure 20. A flow diagram illustrating the stages of commonly observed morphology of the RRME. Adapted from Hart, 2009 pg. 1357.

The long-

the river (Figures 4 and 5) which was also noted by Kirk (1991) and Todd (1998). However,

south before 1976. No links with river flow or

wave data were obtained but a possible reason for this is the location of the main river flow further south than it is today (Figure 21).

Figure 21. Image of the RRME showing extinct river channels further south of the main flow than in more rec

south of the river mouth in previous years such as 1954, 1965, and 1976. Images sourced from Google Earth Pro and was taken on the 8th of July 2009.

accreting. This is similar to results found by McHaffie (2010), in her study of the Rakaia

RCN1830 has also displayed a widening of the barrier bar (Figure 14). This is supported by long-term accretion and increases in sediment volumes. The mean sediment volume between 1986 and 1991 was 150.23m3/m, which increased to 203.34m3/m between 2013 and 2019. This is most likely due to the influence of the northern longshore current in this region (Figure 23). The accretionary trend and widening of the barrier bar occurring at RCN1830 are important elements to incorporate in a baseline of the RRME.

6.4 Erosion

6.4.1 Cut back into bank

There was an estimated ~35m of erosion into the bank southeast of the Rangitata Huts (Apx. H). This occurred over a period of 10-

channel interacting with the bank (Todd 1992; Measures et al. 2020) (Figure 24

erode into this landward shoreline, which is classified as lagoon retreat (Kirk & Lauder as cited in Ha

1999; Todd, 1998), which means that the erosion rate has accelerated in the past 10-years. In terms of long-term

2020). The erosional distance between the 2-yearly images tends to be around 10m at its greatest point (Apx. H)

6.4.2 Erosion south of the river mouth

RCN1548, south of the river mouth, has been eroding since 1989 (Figures 6 and 7). This is due to sediment deposited at the coast and high-energy waves (Hart, Marsden, & Francis, 2008). The Rangitata River is considered a small river (Kirk, 1991). This means that the amount and type of sediment deposited at the coast is insufficient to maintain the coastline against the high-energy waves and longshore transport (Zenkovich, 1967). The Rangitata R

6.7 Outlet migration

The prevalence of southerly waves in the Canterbury Bight generates movement of sediment along the shoreline in a northward direction (Kirk 1991; Leckie, 1994;). This can influence the river outlet position (Todd, 1998). An outlet migration of 800m over four months was identified in imagery (Figure 18). Comparisons with wave data highlighted that the dominant wave direction during this time was from the south. The beach excursion and sediment volume plots (Figures 6 and 12) further cement the interpretation that the northern longshore current is the driving influence of the northern outlet migration (Paterson et al., 2001). Outlet m

(Pg. 1358) or during periods of low flows and low energy waves.

7. Limitations

The river flow and wave data provided some limitations for this research. The data source locations are inadequate for identifying conditions at the RRME. Thus, flow and wave

hese

datasets. There were also issues when it came to synthesising results due to each data set being recorded over irregular periods. The beach profiles were measured annually but at during different months. Between 1998 and 2006 there were no available aerial images, making trend identification difficult. During digitisation it was difficult to determine tide stage, exact flow, and differences between wet sand or shallow water due to georeferencing issues and poor resolution.

8. Conclusion

The RRME is

drivers of geomorphic variability. This research project created a baseline study of the RRME. Similar studies have not been completed for some time and changes to the environment are inevitable. Data used for this analysis was aerial imagery, beach profiles, wave data, and river flow data. Key elements of geomorphic variability found through this study is a northward migration of the outlet channel, breaching of the barrier bar during flood events, erosion to the south of the river mouth, and accretion in the north. These trends can now be incorporated in an understanding of the normal variation seen at the RRME.

9. Further research

Conducting a baseline study for the RRME has created a reference point to guide future research. Focusing on controls outside of this research scope such as tides, tectonic uplift, and erosion rates may add value to future studies of the RRME. Further monitoring of climate change aspects may lead to changes in research methods and approaches. Finally, consistent and reliable image sources showing variations could be advantageous for continued research.

10. Acknowledgements

We would like to acknowledge our supervisor, Seb Pitman for his help and guidance throughout this research. We would also like to recognise our community partner, Justin Cope for bringing forth this research and for his advice and input throughout. LatfE4dc92 reW*nBT/F1 12 Tf

11. Appendices

Appendix A

Mixed-sand and Gravel (MSG) Beaches

The Rangitata Hāpua is located along a MSG beach. Storms are key drivers of morphological change on MSG beaches (Losada et al., 2016). Losada et al. (2016) found that during a storm, a concave beach face developed and the berm, which is in the foreshore during low energy conditions, was eroded. Overall, it is suggested that the profile of the barrier changes with respect to a balance between marine and fluvial processes (Hart, 2009; Kirk & Lauder, 2000; Measures et al., 2020; Single, 2011).

Appendix B

Beach profile analysis

Insert figure 9 B2

Insert figure 13 B3

Figure B1. Beach envelope for RCN1548 for 1981 to 2019, which shows the minimum and maximum extent of the beach face. This envelope demonstrates

Appendix C

Summary of Observed Features Before, During and After Two Flood Events

The below tables are observations made of the two flood events discussed in this report. Other floods were analysed but these were the chosen representative examples. Data sourced from ECan and Planet Labs.

Table C1. Table showing observations and measurements of the Dec 2019 flood sequence of a maximum flow of 2248m3/s. The largest observed changes from this flood was the convex shape the barrier bars formed as they moved seaward during this event. There was significant erosion noted SW of the northern huts.

Date of analysed image	River flow (average for the day in $m^{3/}s$)	Hāpua closed or open?

Appendix D

Analysis of wave data

Figure D1. Histogram showing significant wave height counts recorded for 1999-2019. The most

Table D3. Table showing wave direction and significant wave height annual averages for 1999-2019. The average wave direction is from the south-west and this aligns with the work of Pickrill & Mitchell (1978) who found that the east coast of the South Island of New Zealand is battered by mostly southerly swells, although the mixed wave climate also brings some northerly and easterly waves shoreward.

Appendix F

Rain and river flow for two flood events

Figure F1. Rainfall at Mistake Flats Rain Gauge (December 2019) and Rangitata River flow at Klondyke for the associated period. Data source is ECan.

Figure F2. Graphs showing rainfall at Mistake Flats Rain Gauge (November 2018) and Rangitata River flow for the corresponding week. Data source is ECan.

Appendix G

Qualitative and quantitative analysis of imagery

Visual observations and measurements were used to compile Table F1 while further interesting observations are noted in Figure F2.

Table G1. Table showing observations made for the available images between 1937 and 2020 excluding images from Planet Labs. Data sourced from ECan, Planet Labs, Retro Lens and Google Earth pro.

Date	Source of image	River flow in m3/s	Barrier bar(s) closed or open to ocean?	Hāpua closed or open to river flow?	Channel location (north, central or south of main river flow)	Outlet channel width	Bar width at beach profile RCN1782 location

10th Aug 2020	Planet Labs	No data	Barely open	open	Central but slightly north	Unmeasurable as so small <8m.	45m
1st Dec 2011	Google Earth Pro	105	Open at north end	Open	North	30m	40
26th Feb 2012	Google Earth Pro	90	Open at north end	Open	North	25m	50m

17th