The influence of structures on erosion of the north bank of the Mokihinui River mouth

Prepared for West Coast Regional Council

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This report provides advice on the causes of recent erosion of the true right (northern) bank at the Mokihinui River mouth. The advice was sought by West Coast Regional Council (WCRC) after local concern that this erosion has been influenced by historic river training and coastal protection works.

The investigation included a field inspection, compiling a history of river and coastal protection, analysis of shoreline and riverbank shifts at the river mouth and changes in river mouth configuration from aerial and satellite imagery, and inspection of river flow, sea level, and wave records.

Both coastal and river processes appear to be influencing the north bank erosion at the Mokihinui River mouth.

The site is exposed to storm waves arriving while the sea level is high (notably on high tides with storm surge), and refraction of waves across the river mouth bars focusses wave energy around the "elbow" of Gentle Annie Road.

The river channel is generally forced to run alongside the north bank by two drivers:

- Northward-prevailing littoral drift deposits sand on the bulge inside the south shore spit-tip, which forces the river alongside the north bank at normal flows. While large floods periodically trim the sand bulge off (and flush it seaward), they don't do this instantly so that for part of the flood duration high flows will be concentrated along the north bank.
- The river outflow is deflected to flow hard along the north bank by the training wall on the south bank.

The south bank river training wall therefore has some influence on the north bank erosion, but by deflecting flood momentum it also helps keep the river from attacking the south shore spit-tip and the estuary side of Mokihinui township.

The spit-tip groyne has only minimal effect on sand transfer into the river mouth and so exerts little control on the growth of the sand bulge.

The remnant of the north bank training wall, now largely in the river channel because of bank retreat, still provides some stabilising function so its removal would likely exacerbate the north bank erosion.

Under the status quo, the most vulnerable area on the north bank (the "elbow" on Gentle Annie Road) is likely to become more vulnerable as sea level rises and if storm surges and waves intensify. A pragmatic solution would be to shift the road behind the Gentle Annie campground. The alternative mitigation is expensive rock protection.

1 Introduction

This short report provides advice on the causes of recent erosion of the true right (northern) bank at the Mokihinui River mouth. The advice was sought by West Coast Regional Council (WCRC) after local concern that this erosion has been influenced by historic river training and coastal protection works. WCRC wish to know if these structures are having an effect on this erosion and, if so, why.

The investigation included:

- a field inspection (9-10 February 2019)
- compiling a history of river and coastal protection
- analysis of shoreline and riverbank shifts at the river mouth and changes in river mouth configuration from aerial and satellite imagery
- inspection of river flow, sea level, and wave records
- preparing this report.

2 River and coastal protection structures

Structures around Mokihinui river mouth aim to provide protection against erosion and flooding by both river and coastal processes. As located on Figure 2-1, they include:

- **River training wall**. A ~100 m long rip-rap training wall (rock deflector groyne) on the left river bank, built in 1978 (initially 50 m long but extended by another 50 m in 1981) with the purpose of training the river flow away from the Mokihinui village.
- **Estuary stopbank**. A 960 m long rock-armoured, compacted-gravel stopbank running around the south shore of the estuary and out onto the spit, built in 1952 to protect the village from river flooding.
- **North bank training wall**. The remnants of an originally ~ 150 m long riprap wall holding the north bank at the road elbow, built in 1978 but now largely collapsed/stranded in the river. Rock has been placed relatively recently on the seaward side to protect the elbow of Gentle Annie Road. It appears that the purpose of this structure was to "prevent the river sweeping to the north"[1].
- **Stub groynes** on north bank. Two short stub groynes further upstream from the north bank training wall. I have found no clear information on when these were built, but it is likely during the late 1970s.
- **Spit-tip groyne**. A ~ 40 m long rock groyne at the northern tip of the Mokihinui spit, built in the 1960s and added to/repaired on occasion. It abuts the north end of the double bund.
- **South shore double bund**. A sandy gravel double bund extending ~ 800 m south from the spit-tip groyne. The purpose is to protect the village from sea flooding. The front bund is sacrificial, while the landward one is a backup for when the front one inevitably fails. First constructed in 1969, the system has been rebuilt several times, each time shifting landward as the coast has retreated.
- **Spur groynes**. There are four of these, keyed into the seaward bund that fronts Mokihinui township. They were built recently to serve as strongpoints on the seaward bund and to encourage the natural accumulation of a cobble ramp in front of the bund to help it withstand wave attack.

Most of these structures are managed by the Mokihinui Rating District with an Asset Management Plan (WCRC 2014). They aim to protect against medium sized events but appear not to have been designed to any particular return period event. It is not clear who, if anyone, has responsibility for the north bank structures as they are not included in WCRC (2014).

[1] Letter dated 27/7/1973 to the County Clerk, Buller County Council, from the Chief Engineer, Ministry of works.

Figure 2-1: Photo-map locating structures at Mokihinui River mouth. Image from Google Earth (photographed 2018).

3 Field inspection

The river mouth and adjacent beaches were inspected on 9/2/2019 at mid-tide and again on 10/2/2019 at low tide. The main observations were as follows.

On the north bank:

- The beaches adjacent to the river mouth appear to have abundant sand stocks (relative to my past observations over the period 2007-2010).
- The gneiss and granite boulder-grade road-verge protection at the elbow were collapsing down the bank (Figure 3-1), apparently due to undercutting by waves (because they face seaward and are sheltered from the river's current by the training wall just upstream).
- Erosion embayment's occur in the north bank upstream from the remains of the north bank training wall (Figure 3-2); the erosion of the cobbly bank material has left a cobbly lag-beach in front of the bank which will be providing minor protection services; however, there is some danger that the remains of the training wall will soon be outflanked and isolated (like the upstream ends of the wall have been already).
- The river channel is forced alongside the north bank through two effects: the sand bulge on the inside of the south bank spit and the flow deflection by the left-bank river training wall.
- The river bank profile rises steeply from the channel bed (at about 40 degrees), then has a beach/berm up to 20 m wide before erosion scarps are encountered (Figure 2). The low tide channel bank-line is supported by the extended remnants of the north bank training wall (Figure 3-2), even if this is now submerged at high tide and flows. Thus, while direct river attack does not appear to be the mechanism by which the higher segments of bank are being eroded, the river will be helping clear the eroded material and it remains forced alongside the north bank.
- The erosion seaward of the two stub groynes appears relatively recent (Figure 3-3), but the erosion upstream appears to be older, as evident by vegetation grown over the erosion scarp (Figure 3-4).
- Further upstream, bedrock exposure and tree roots protect the bank-line.

On the south shore:

- The seaward bund is composed of gravelly sand scraped from the upper beach. Its face is steep, and around the access point at the end of Lewis Street it is at the repose angle, showing that it is being "chewed" by waves at high tide (Figure 3-5). The upper foreshore is formed by a narrow ramp of cobbles, while the mid-lower foreshore is wide and sandy.
- The four rock spur groynes (~ 10m long spur, ~ 20 m long base) keyed into the seaward bund appear to be having minor/minimal effects. I saw no sign of any sand/gravel impoundment wedge adjacent to the southern spur groyne (near the macrocarpa trees; Figure 3-6), but there was a narrow upper foreshore gravel wedge between the 2nd and 3rd spur groynes and between the 4th spur groyne and the spit-tip

groyne (Figure 3-7). The wedge orientation indicated northward transport, as expected, but the “thick end” width was only several m, so the protective services developed will be minimal. Thus, these spur groynes appear to be too short to have any significant effect.

- The spit-tip groyne, while extending 40 m across the mid-upper foreshore, is a small feature at the river mouth scale (Figure 2-1) and is too short to trap much sand – since longshore transport occurs in the surfzone which is only partly penetrated by this feature even at high tide. Thus, while it will be having a small local effect, sand will largely be bypassing it.

Figure 3-1: View upstream on north bank to the root of the training wall. Rock riprap in front of campervans has partially collapsed.

Figure 3-2: View upstream on north bank along remnants of training wall.

Figure 3-3: View seaward on north bank, showing relatively recent erosion "bite" into cobbly terrace fronted by cobble lag beach.

Figure 3-4: Close-up of vegetated-over erosion scarp between north bank stub groynes.

Figure 3-5: Double bund fronting Mokihinui township. Note steep (at angle-of-repose) seaward face of seaward bund, cobble ramp on upper foreshore, and wide sandy lower foreshore.

Figure 3-6: The spur groyne south of Lewis Street. Note no difference in width of cobble ramp either side.

Figure 3-7: The 3rd and 4th stub groynes and the spit-tip groyne in the background. Note northward thickening of cobble ramp towards the nearest (3rd) groyne.

4 Shoreline and riverbank shifts at/around the river mouth

Historical shoreline positions along the Mokihinui embayment, from the late 1800s to 2007, were mapped by Hicks et al. (2007) as part of Meridian Energy's investigations around effects of the proposed Mokihinui hydro project (Figure 4-1). These showed that north of the Mokihinui River the shoreline built seaward between 1906 and 1987 but then retreated. The 1906 cadastral shore/bank line shows that the river outflow then was more normal to the general shoreline trend (i.e., the river flowed straight out to sea), but since around 1955 the outflow has deflected north, with up to ~150 m of erosion off the north bank before 2007. South of the river, the shoreline has experienced ongoing retreat since the first cadastral survey in 1898, with rates increasing after 1955 (from 0.5 m/yr to over 1 m/yr). Shoreline recession rates taper-off with distance north and south of the river.

Hicks et al. (2007) considered that these historical patterns were due in part to a phase of relatively high sand and gravel supply from the Mokihinui River following the 1929 earthquake, which would have taken some decades to pass down the river. North of the river the sediment pulse resulted in a period of rapid coastal accretion fed directly from the river. South of the river, where the coastal plain has been formed largely from littoral drift material that has collected against the river delta, the river sediment pulse would appear to have temporarily slowed a long-term erosion trend. This erosion trend appears to have prevailed again as the river supplies have reduced. They considered that the general erosion trend has a mixture of causes, including sea-level rise and a reduced supply of littoral drift material from the south due to sediment entrapment at the Buller river mouth breakwaters.

Finer details of the recent positions of the north bank are shown on Figure 4-2. On this, bank positions were mapped from georeferenced vertical aerial photographs taken in 2007, 2010, 2016, and February 2019. This shows an overall bank retreat of up to 21 m along the ~ 300 span of bank upstream from the 'elbow' between 2007 and 2019, but with most of this occurring between 2010 and 2016 (which included the two largest recent floods of late 2010 and late 2011) and a lesser amount between 2007 and 2010. The bank retreat shows a 'cusped' pattern, with retreat greater in shallow embayment's between cobbly headlands (similar to the pattern observed on cusped gravel beaches). Less overall retreat occurred between 2016 and 2019 (which includes Cyclones Fehi and Gita in February 2018), but 2-8 m of retreat over this period was focussed on WSW-facing banks on the seaward sides of the cusps – which suggests erosion by waves rather than high river flows.

Further upstream, the 170 m span of bank enclosed by the two stub groynes has remained stable since 2010 (within the 1-2 m level of detection afforded by the aerial imagery).

Seaward of the elbow, the bank (or at least the vegetation edge) has advanced up to about 20 m since 2007.

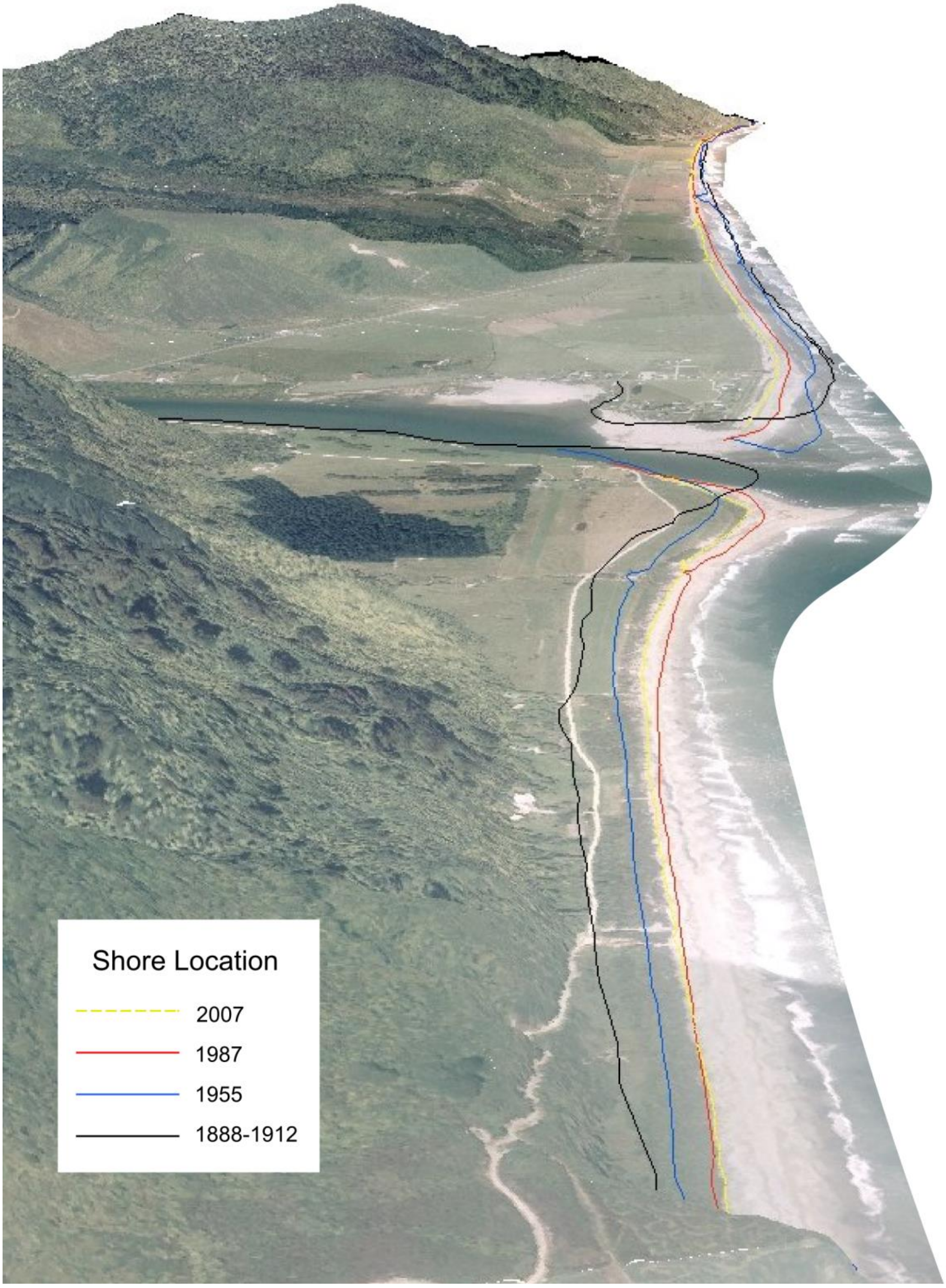

Figure 4-1: Panorama view south from Gentle Annie, showing historical shoreline positions overlaid on 2007 image. From Hicks et al. (2007).

Figure 4-2: North bank locations between 2007 and 2019 overlaid on 2019 imagery. Bank/shore edge positions mapped off edge of vegetation on georeferenced imagery.

5 River mouth configuration patterns

Figure 5-1 shows little change to the basic river mouth pattern since the 1960s, with the river mouth consistently deflecting north of the centreline and a spit (or shoreline bulge) always present on the southern bank. More detailed time-series imagery extracted from Earthengine[2] over the period 2008-2018 shows that the spit waxes and wanes in size, forcing the river more or less towards the north bank, while the outflow across the Rivermouth bar "thrashes around" over an arc of about 40 degrees. The 1966 photograph (Figure 5-1) appears to have the greatest northward deflection, and this concurs with comments made in 1972 that "the present outlet which is well to the north of the township and is resulting in a loss of effective head to the sea"[3]. The construction of the north bank training wall in 1978 would have restricted this northward deflection tendency.

[2] https://earthengine.google.com/timelapse/
[3] Letter of 10/2/1972 to Commissioner of Crown Lands from the Chief Engineer, Ministry of Works.

Figure 5-1: Aerial photographs of the Mokihinui River mouth from 1966 to January 2019. 2011-2019 imagery from Google Earth.

6 River flow, sea level, and wave records

Records of the "forcing functions" – the river flow[4], sea level[5], wave height, and longshore transport potential[6] – since 2008 are shown in Figure 6-1, along with images extracted from Earthengine[2].

The largest river flood (peaking at 2875 m^3/s) occurred in December 2010. Note on the 2010 and 2011 images at the top of Figure 6-1 how the sand "bulge" on the south side of the river mouth was largely trimmed off after this flood (but built back in subsequent years).

The highest sea level of recent years (~ 1.5 m above normal high tides) was the storm surge associated with Cyclone Fehi on 31 January 2018[7]. Fehi also provided the 3rd highest wave event since 2008, and so was the likely cause of the most recent erosion on the northern river bank (attack from seaward was also indicated by the westward aspect of the erosion "bites"). Higher wave events occurring in November 2011 and July 2016 (but with less storm surge) might account for the erosion recorded between 2010 and 2016.

The record of wave-driven longshore transport potential indicates to both north and south on a day by day basis but with northward transport dominant and the highest transport events all directed northward. This northward transport, and waves wrapping around south shore spit and pushing sand into the river mouth, are inferred to be the process driving the build-up of the sand bulge on the south bank of the river mouth.

[4] River flow recorded at the Welcome Bay gauge operated by WCRC.
[5] Sea level recorded at Charleston, which should be reasonably representative of that at Mokihinui.
[6] Wave records are hindcast at the 10 m depth-contour off Mokihinui from regionally-downscaled global wind models. The 1 January 2008 through 15 June record was derived using a 12 km model grid; the remainder of the record trough to 30 July 2018 was derived from an 8 km model grid. Wave height is represented by the significant wave height (average height of the highest 1/3rd of waves). The longshore transport potential was estimated using the equation of Ashton and Murray (2016). Positive transport is towards the north.
[7] Note that the very high sea-levels recorded on the Charleston gauge in 2011 appear to be excessive (due to instrument malfunction during September 2011 and local oscillation forced by shelf waves in the Charleston embayment in July 2011).

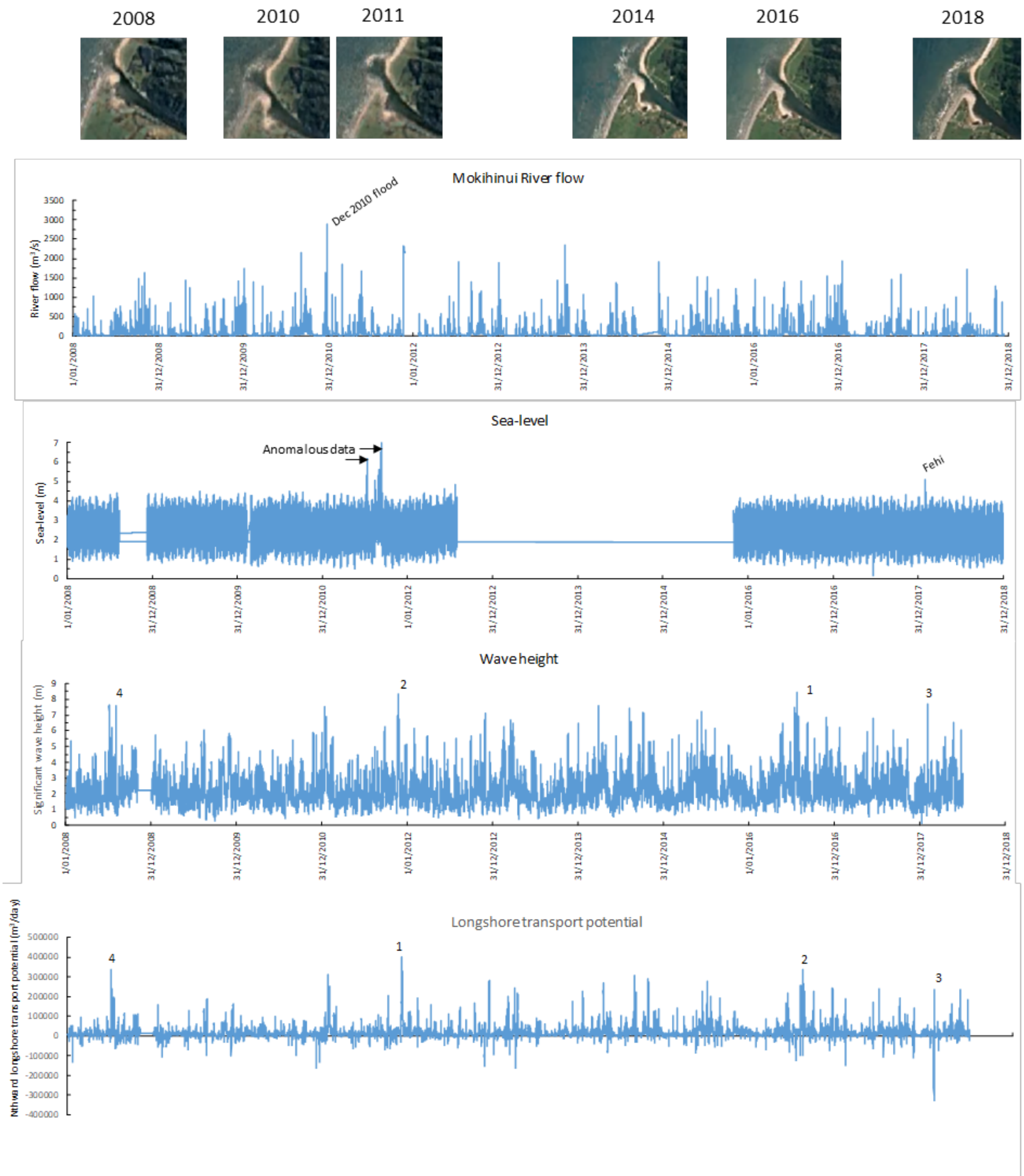

Figure 6-1: River flow, sea level, significant wave height, and longshore transport potential at Mokihinui since 2008. River mouth images from Earthengine shown at top. Numbers 1-4 on wave height and longshore transport potential plots rank the four largest events. The 28 December 2010 river flood peaked at 2875 m^3/s.

7 Estuary cross-section

A further piece of useful information is an estuary cross-section that was surveyed by NIWA during the Mokihinui hydro-power investigations (Figure 7-1). This was surveyed in February 2011, shortly after the large flood of December 2010, and shows the channel midway down the estuary having an asymmetric shape, with the thalweg hard against the steep right bank. This provides evidence of the effectiveness of the left bank training wall at deflecting flood momentum along the north bank.

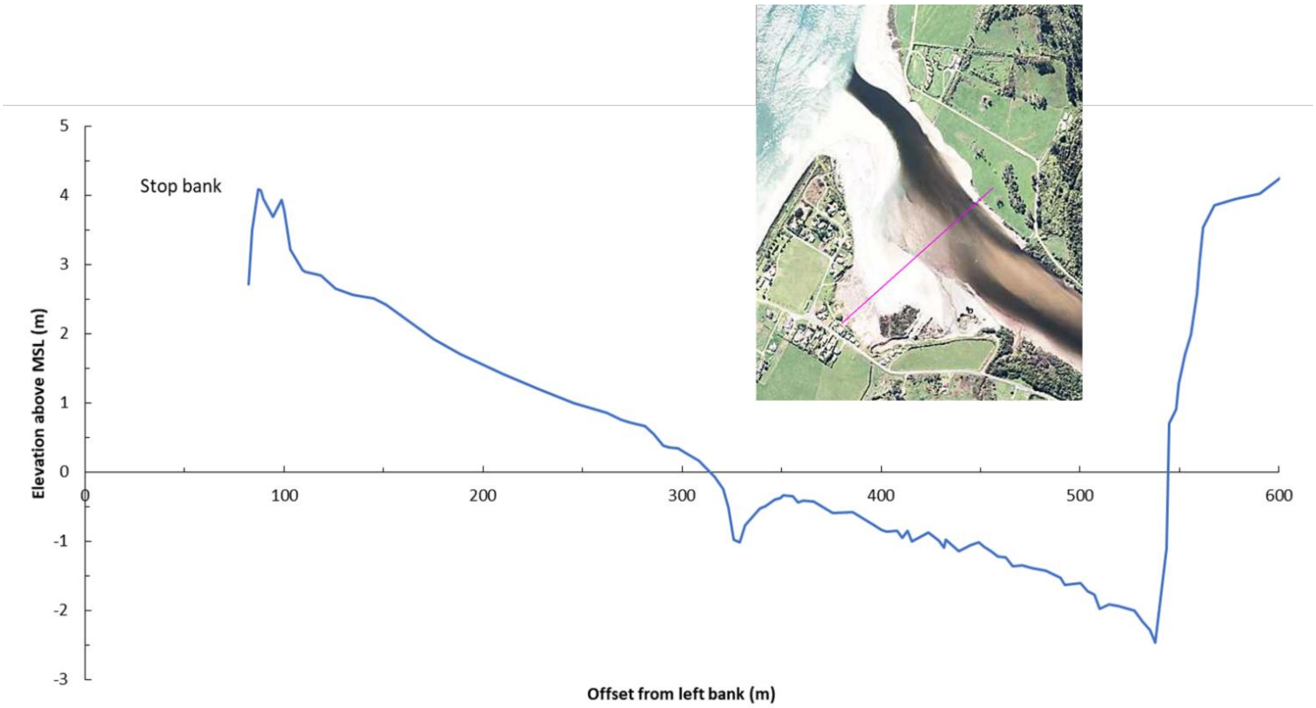

Figure 7-1: Mokihinui cross-section surveyed in February 2011. Section located by pink line on inset image. Wet part of channel surveyed by echo-sounder linked to RTK-GPS; dry parts from prior LiDAR survey. Source: NIWA.

8 Conclusions and recommendation:

8.1 Main drivers of north bank erosion

Both coastal and river processes appear to be influencing the north bank erosion at the Mokihinui River mouth:

- The site is exposed to storm waves arriving on a high sea-level (notably on high tides with storm surge). Refraction of westerly-quarter storm waves across the river mouth bars and outlet channel will focus these waves onto the north bank “elbow”, and so these will continue to take erosion “bites” from this area at relatively high levels up the bank.
- The river channel is generally forced to run alongside the north bank by two drivers. First, northward-prevailing littoral drift deposits sand on the bulge inside the south shore spit-tip. This forces the river alongside the north bank at normal flows, and while large floods trim the bulge off (and flush it seaward), they don’t do this instantly so for part of the flood duration the flood flows will be concentrated along the north bank. Secondly, the river outflow is deflected to flow hard along the north bank by the training wall on the south bank.

8.2 Effects of existing structures on north bank erosion:

The effects of existing structures on the north bank erosion are summarised in Table 8-1.

Table 8-1: Extents to which existing structures influence erosion at the north bank of the river mouth.

Structure	Affecting north bank erosion?	Reasoning
North bank training wall	Yes, but positively	This structure, although now largely in the river, still provides a stabilising function. Removing the riprap from this remnant structure would likely exacerbate the north bank erosion.
North bank stub groynes	Yes, but positively	Appear to be effective as no significant erosion surveyed between these.
South bank river training wall	Somewhat	Directs river momentum along northern bank, but by doing this it helps keep the river from attacking the south shore spit-tip and the estuary side of Mokihinui township.
Estuary stopbank	Potentially in a small way	Without this stopbank, large floods could break-out through Mokihinui township, reducing the river flow past the north bank.
Spit-tip groyne	Minimal	Has only minimal effect on sand transfer into the river mouth (a longer groyne/training wall would hinder build-up of the littoral drift-fed sand bulge, which would

		reduce the river pressure along the north bank).
Structure	**Affecting north bank erosion?**	**Reasoning**
South shore double bund and spur groynes	No	Have minimal effect on sand transfer north into the river mouth.

8.3 Recommendations

The most vulnerable point on the North bank is the right-angle corner (i.e., the "elbow" on Gentle Annie Road). Under the status quo, this will continue to be vulnerable to erosion by high waves on storm surge and high river flows; indeed, it is likely to become more vulnerable as sea-level rises and if storm surges and waves intensity (e.g., more frequent equivalents of Cyclone Fehi).

A pragmatic solution would be to shift the road behind the Gentle Annie campground. The alternative mitigation is expensive rock protection.

Removing the riprap from the remnants of the north bank training wall would likely exacerbate the north bank erosion. This is because this material still provides some bank-stabilising function.

9 Acknowledgements

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