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memorandum

TO	Simon Mapp	FROM	Ramon Strong
	Emergency Management Southland	DATE	25 March 2024
RE	Waiau River Mouth Opening		

1.0 Introduction/ Background

Erosion has occurred along the coastline at the mouth of the Waiau River, adjacent to Bluecliffs Beach Road, potentially threatening a group of houses. The erosion is associated with both the presence of a high (measured at around 6m on 6 March) and extensive gravel bar across the river mouth as well as high flows in the Waiau River, the latter associated with both the September 2023 event and a prolonged period of wet weather for Fiordland over the past few months, elevating the levels of Lakes Te Anau and Manapouri.

Earthmoving machinery has been used in an attempt to breach the gravel bar to provide relief. While that work appears to have come close to meeting its objective, a more direct path for the river to the sea was not able to be achieved. Emergency Management Southland (EMS) have engaged Pattle Delamore Partners (PDP) to provide an opinion on whether further efforts to achieve that objective are warranted, i.e. an estimation of the likelihood of success with further work.

This short report is based on desktop analysis by PDP staff (including a review of a Tonkin and Taylor – T&T – report), a helicopter inspection (accompanied by Environment Southland – ES - staff) and a telephone discussion with the contractor tasked with making the cut through the bar. Note that the T&T report is ostensibly a geotechnical report and as such only the reference information collated for that report has been used in our assessment.

It is important to note that our report is not an exhaustive one and the natural processes at play are complex: the power of the Southern Ocean, the complex geology and active tectonics of the area and the regulated nature of flows in the Waiau River. Accordingly, the commentary related to the geomorphology and coastal processes are cursory given the time available.

2.0 Environmental Setting

2.1 Geology and Landforms

The site (and a large portion of the Waiau River) is situated within the Waiau Basin, which is controlled by subsidence along the Moonlight Fault System. The basin is infilled with Tertiary rocks which are overlain by extensive flights of Quaternary terraces, which were deposited by the Waiau River draining the former Te Anau-Manapouri piedmont glacier and other Fiordland glaciers (Turnbull and Allibone, 2003). The Waiau Syncline lies within the basin, with the river located on the eastern limb.

Figure 1: Landscape features around the river mouth

The Lower Waiau River extends for 70 km from Lake Manapōuri south to the coastline at Te Waewae Bay south of Tuatapere. Prior to hydroelectric generation the Waiau was (based on mean flow) New Zealand's second largest river (Ellis and Palliser, 2019) but with the construction of the Manapōuri Power Station (MPS) and the Mararoa Control Gate (the weir) flows have reduced and are more regulated. The MPS became fully operational 1972 and a second tailrace tunnel was completed in 2002, enabling greater generation.

Figure 2 shows the ten largest flow events in the Waiau at the Tuatapere flow site (NIWA, 2024). It is noted that of these ten floods, four happened in the 5-years between 1979 and 1984. The September 2023 event is thought to have led to increased erosion along Bluecliffs Beach Road. This was the third largest event (peak flow) on record.

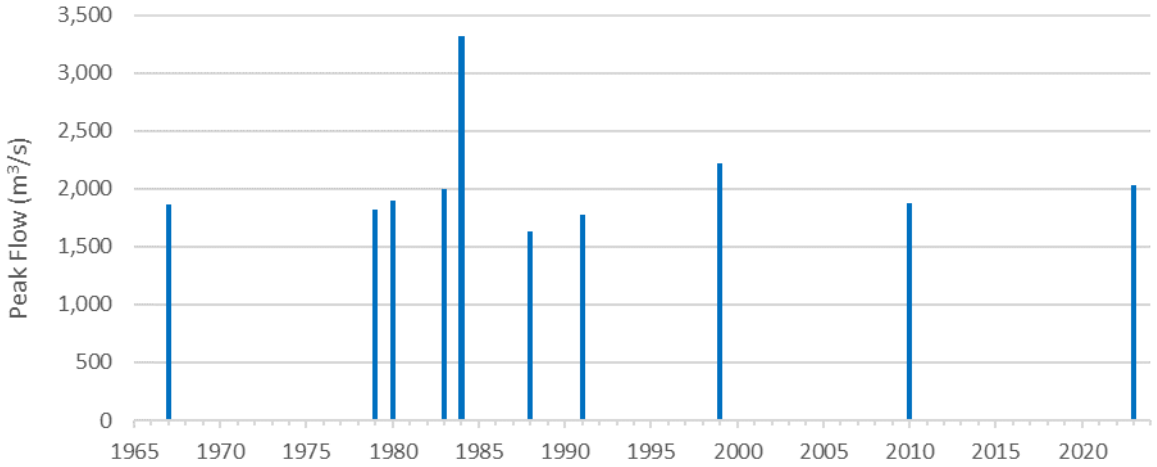

Figure 2: Ten largest events on record (Waiau at Tuatapere).

The Waiau River exits to the coast as a river delta/fan into the centre of an approximately 27 km-wide coastal embayment known as Te Waewae Bay. Te Waewae Bay faces south-southwest into the persistent southwesterly winds and high-energy waves of the south Pacific/ Southern Ocean. The Waiau River mouth is a hāpua-type lagoon; a system known more broadly as barrier-beach enclosed, wave-dominated river system, stream river mouths or river mouth lagoons (Hume et al., 2016). Hāpua-type lagoons generally that have no tidal inflow into the river (i.e., no tidal prism), although can temporarily experience tidal includes for short periods (i.e., hours to days) after large flood breaches before longshore transport by waves re-establishes the barrier.

There is limited information on the coastal sediments and coastal processes in this area. The beach appears to be a mix of sand, with gravel and cobbles largely on the upper beach face, likely largely sourced from the Waiau River, and longshore drive in the vicinity of the Waiau mouth is east to west which is unlike Southland in general (Robertson and Stevens,2008). Currently, the Waiau hāpua (lagoon) extends in both directions alongshore impounded by the estimated 40–70 m-wide (to latest high mark) sand/gravel barrier that is up to 8 m high.

2.2 Waiau river mouth and hāpua[1] dynamics

The physical processes that control the morphology of hāpua and their associated river mouths are complex interactions of wave- and river-driven sediment transport and hydrodynamics (Hart, 2009). The impacts of coastal storms on river mouth dynamics and closure are also somewhat unpredictable, as wave action during storms can close mouths by deposition or alternatively open hāpua when wave activity breaches the barrier, especially if river flows are low to moderate (Todd, 1983). Thus, if/when the barrier of hāpua systems breaches, how long breaches can stay open (whether the breaching process was natural or artificial) depends on the balance between river flows and wave energy/ littoral drift.

McSweeney *et al.* (2016) summarised the three key scenarios causing gravel barrier closure (based on the Opihi river mouth/ hāpua system), which were: (1) summer low flows; (2) fluvial slug deposition; and (3) coastal storms. They also noted that barrier closure duration was longer during low river flows, when offshore wave energy is high, and when the outlet channel is considerably offset. Furthermore, sufficient hydraulic head is required to maintain and open the outlet against the high levels of wave energy and longshore sediment transport (McSweeney et al., 2016).

[1] Hāpua - a river-mouth lagoon on a mixed sand and gravel (MSG) beach, formed at the river-coast interface where a typically braided, although sometimes meandering, river interacts with a coastal environment that is significantly affected by longshore drift (Wikipedia).

2.3 Impacts of Manapōuri Power Station (MPS)

It's not possible to consider the issue of Waiau River mouth processes without giving consideration to the regulation of flow in the Waiau, and in that regard to date there has been limited focus on the impacts to hāpua from flow diversion.

With the Opihi River mouth hāpua in Canterbury, there were less river mouth closures after dam construction due to a more constant flow regime maintained by the dam. However, seasonal patterns of closure still occurred in summer, showing that wave-driven processes were still important in determining the entrance condition (McSweeney et al., 2016). Conversely, in the Waiau River, the MPS has significantly decreased the average river flows, which has likely resulted in more frequent and more persistent closure of the gravel barrier directly fronting where the Waiau river meets the coast. Robertson and Stevens (2008) noted that prior to the establishment of the MPS, the Waiau mouth moved along 4 km of coast without fully closing and that since then, closures occur when periods of low river flows coincide with high-energy seas.

The aerial photo sequence analysed (1946 to present day) suggests that the mouth is more prone to offsetting now than it was in its previously unregulated (or less regulated – the major catchments all contain lakes that provide a degree of regulation) state. However, it is acknowledged that review of historical aerial imagery only provides a snapshot in time and cannot be completely relied on to review the spatial variation in processes that were occurring.

3.0 River Mouth Change

A summary of the changes observed in aerial photos[2] is provided in Table 1. Rows highlighted in orange indicate when river mouth was observed to discharge through the gravel barrier at the river mouth.

It is apparent from this review that the Waiau River mouth is a highly dynamic and complex system; the processes operating are a balance between wave and river energy and sediment supply. It appears that while there are decades of time where the river appears to consistently discharge at the river mouth, a change in processes can lead to considerable change, as identified through the somewhat rapid development of the lagoon to the west of the mouth (in front of Bluecliffs Beach Road) or the breaching of the bar during the September 2023 event. Equally, at other times the gravel bar has been observed to completely close (2022-2023 imagery) or can quickly build up and reestablish, as observed during the recently attempted works (February – March 2024).

Table 1: Summary of changes to the Waiau River mouth	
1899 map	This map shows the sand/gravel barrier is closed directly in front of the mouth, and that there is a defined lagoon extending both east and west alongshore. There appears to be a narrow outlet in the barrier west of the river mouth, near Waimotu Creek.
1946	The river discharges from an outlet directly in front of the river. It is a wide, dynamic entrance. There is a lagoon to the east of the mouth, which looks to be associated with Kowhai Creek.
1950	As above, but the outlet has narrowed. There are also isolated lagoons on the upper beach to the west of river.
1955	As above but outlet has narrowed further.

[2] Aerial images were obtained from Retrolens, MapsPast, ES online historical imagery database and Google Earth.

Table 1: Summary of changes to the Waiau River mouth	
1963	As above but outlet is now split by a shoal into two and is slightly offset west towards Kowhai Stream.
1964	As above but outlet is now a single, well-defined channel that is angled towards the west (rather than perpendicular to the coast).
1969	The river is discharging through an outlet located directly in line with the lower reach of the river. A more established lagoon has begun to form and extend west. Isolated/disconnected lagoon bodies remain present further west. This point in time marks the first instance where the river mouth has connected to the lagoons behind the gravel barrier.
March 1975	The river outlet has begun to offset to the west and is discharging opposite Kowhai Stream). The lagoon is becoming more defined in both directions alongshore.
1979, 1980, 1983 and 1984 flood events. 1984 is biggest on record (with a peak flow of 3,320 m^3/s at Tuatapere).	
1985	By 1985, significant change to the river mouth had occurred. There was a single, constricted outlet at the river mouth, which is directly is connected to a lagoon to the west. The lagoon west of the mouth is ~2.2 km in length and is fully connected over this length. It is more defined and appears deeper.
1989	As above, but the outlet has widened.
1992	As above, but the outlet is very narrow and has begun to offset to the west.
1998	At this time, it appears that the gravel barrier has closed directly in front of the mouth. It is unclear where the outlet is (imagery not available), although likely further west as the lagoon is wider and deeper on the western side when compared to the eastern side. The western side of river mouth is now highly vegetated.
2003	The barrier remains closed directly in front of the mouth and the river is discharging through outlet at far western end of lagoon, between Cameron and Waimotu Creeks (~2.2 km from river mouth).
2010	River is discharging through small outlet at the river mouth. It appears that the lagoon to the west has infilled with sediment opposite the properties along Bluecliffs Beach Road.
2012	As above.
2013	By 2013, the outlet had offset to the west to opposite Kowhai Creek. The pocket of gravel in front of the properties was still present.
2019	The barrier was closed at the river mouth and the outlet has offset to the far western end of the lagoon (between Waimotu and Cameron Creeks). The gravel in front of the properties is no longer visible.
2020	As above.
2021	As above but the outlet has offset further west to opposite Cameron Creek.
2022	As above, but the outlet has offset slightly back to the east but remains close to Cameron Creek.

Table 1: Summary of changes to the Waiau River mouth	
Date unknown 2022 - 2023[3]	At some unknown point (likely summer of 2022/2023), it is apparent that there is no outlet to the sea i.e., the gravel bar has closed over.
October 2023	An image provided in T&T (2023) indicates that the gravel bar had been breached opposite the properties along Bluecliffs Road. This is identified to be the time period when significant erosion occurred following the September 2023 flood event.

4.0 Emergency Management Southland Scope

As identified above, EMS have requested advice on whether further efforts to cut an opening through the gravel bar at the river mouth will provide relief to the erosion issues faced along Bluecliffs Road. ES specifically requested comment on the following:

- *Review the current cut arrangements and the methodology used, including use of drone footage and associated photographs and historic imagery held by ES.* The desktop summary undertaken to support this assessment has been summarised above. That assessment has been complemented by an aerial inspection of the Waiau mouth on 1 March 2024.
- *Consider what physical work would be required to seek to improve the efficacy and longevity of this existing cut, to seek for this to last for several months, potentially.*
- *Scope the physical extent of this and likely machinery and hours required.*
- *Provide a professional assessment, based on the above, as to whether it is likely to be achievable to maintain this cut for this type of duration or whether it will inevitably fall victim to the power of the Southern Ocean / tidal influences.*

Anecdotally a cut through the Waiau bar has been attempted before in the 1970s, using Ministry of Works equipment relocated from the Ohai Mine. Little detail exists around the location of the attempt, the prevailing conditions and whether it was successful – none of the machine operators involved in that attempt are thought to be still alive.

Establishing a cut through the gravel bar to allow the river a more direct path to the sea has a range of challenges to it. Firstly, the contractor has noted the difficult conditions on site: the gravels that form the bar are well bound/ tightly packed requiring much greater machinery effort than an initial assessment would have suggested. The contractor also identified a submerged rock ledge resistant to machinery ripping. This is likely geologically connected to the rock outcrops that river erosion has exposed immediately west of the affected houses. If the rock is laterally persistent, this will limit the depth of any cut unless either demolition hammers or blasting is employed, and that in this context would prove to be challenging and expensive.

It's also noticeable from the available photos the volume of gravel that the sea had deposited in the cut in a relatively short space of time; **it would be, in our view, impossible to maintain an open cut for any appreciable length of time unless very favourable conditions (high river flows and benign sea conditions) persisted**. We have considered (and anecdotally there is historic precedent) for a cut further east where the bar is narrower. Clearly the position of the recent cut was driven by alignment with the lower reach of the river to harness the direction of river flow - cuts further east will be less well aligned, and could also have potentially greater impact in regard to the wetland values on the eastern side of the delta.

[3] Imagery available on LINZ as Southland 0.25m Rural Aerial Photos (2023) which were noted to be captured in flying season of 2022-2023.

It is important to note that the contractor engaged by ES appears to have the requisite skills, knowledge and machinery to undertake the task; the work was built around timing the work to coincide with the maximum available head (high river flow and low tide) which is a logical and consistent approach for mouth openings. The constraint of not being able to at least throttle flow in the offset channel, to force more river water through the cut, may have had some minor impedance on success but in the overall context this is not a significant factor. It is our opinion that the cut would simply not survive for more than a few hours given the scale and complexity of the natural processes at play.

In the vein of throttling offset channel flow, suggestion has been made around the construction of a training line to limit offsetting – such a structure would be costly and would not come with any guarantee of success. The Koau mouth of the Clutha River at Molyneux Bay has a substantial training line to prevent a westerly offset, requiring a significant volume of rock rip-rap to build with an ongoing inspection and maintenance cost. The Whanganui River mouth similarly has moles to prevent offsetting (and permit a navigable mouth for access to the port) – Horizons Reginal Council has recently spent at least $10M just to refurbish the North Mole.

A cursory assessment suggests a structure just west of the mouth would need to be at least 200m in length to be effective (tie back into higher ground to prevent it from being outflanked and project far enough into the surf zone to stop river flow from passing around the front of it and back into the offset channel), but it's perhaps the height that's the main consideration. Estimates from the contractor who made the initial cut are that the bar is around 8m in height; survey on 6 March 2024 confirmed a height closer to 6m. Given the bound nature of the gravels that comprise the bar any training line would need to be largely (subject to more detailed analysis) around the same height as the bar to guarantee effectiveness.

At a lesser height the risk would be that river flow would plunge over the top of the structure before sufficient head is developed for river flows to find their way through the bar, destroying the structure. That would require a more substantial structure than the Koau mouth structure with an equally substantial foundation (reflecting the hydraulic head that would be exerted on the structure's foundations); estimating the cost of such a structure is heavily dependent on both the size of the rock rip-rap required (particularly to form the head) and the availability of rock (production and cartage cost). Even a very favourable scenario (a significant volume of large, durable and angular rock close by) would suggest a price tag of at least $10M.

5.0 References

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6.0 Limitations

This memorandum has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Emergency Management Southland, including Tonkin and Taylor Limited. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the memorandum. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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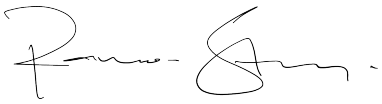

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