Hawkes Bay Regional Council

WAIROA LAND CATEGORISATION

IMPACT OF WOODY DEBRIS AND THE WAIKAREMOANA POWER SCHEME

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FOR EXTERNAL USE

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EXECUTIVE SUMMARY

There was a substantial amount of Large Woody Debris (LWD) in the Wairoa River during Cyclone Gabrielle and its effect was evident on the bridges upstream of Wairoa. LWD can create matts of debris at bridges which can restrict flow, raise flood elevations, causes damage to the structure, and impound and release flood water. The primary source of this LWD appears to be bank erosion / slumping and slips. This is supported by a field survey that found a large portion of the LWD was Willow, Poplar and natives. Two studies have also concluded that there was only minor contribution from forestry harvesting practices (slash).

In the case of the Palmerston North Gisborne Line (PNGL) rail bridge, the debris trapped there would have increased upstream flood levels and contributed to the failure of the approach embankment. The rate at which this failed though is unlikely to have created a sudden and significant release of impounded flood water or contributed in any significant way to the flooding in Wairoa.

Located in the catchment on the Wairoa River is the Waikaremoana Power Scheme. This attenuates flows from the upstream catchment to generate renewable energy. There were community concerns that the scheme's overflow operated creating a pulse of additional flood water to the Wairoa River. However, several reviews of the scheme's operation during Cyclone Gabrielle indicate that the operation of the upstream Waikaremoana Power Scheme did not worsen the flooding experienced in Wairoa and may even have slightly reduced the scale of the flooding by attenuating run-off from the lake's catchment.

Sudden surges of water experienced in North Clyde were more likely due to the topography of the flood plain combined with dynamic flow conditions during the flood. As the land falls toward the coast, water would flow across this area at speed; the area is effectively a secondary flow path of the Wairoa River. The onset of flooding would have been rapid and when combined with turbulence in the river, and the complexities of a rural-residential flood plain would have at times formed sudden pulses of flow, as objects such as fence lines clogged with debris collapsed releasing trapped water.

In conclusion, the flooding was primarily caused by the significant rainfall that fell across the catchment combined with the antecedent weather of the 2022-2023 period and that the sudden onset of the flooding through North Clyde is due to the area acting as a secondary flow path of the river. With or without debris, North Clyde would still have flooded and the Waikaremoana Power Scheme did not exacerbate the flooding that occurred.

1 SCOPE OF ASSESSMENT

The Wairoa community have expressed the view that woody debris or 'slash' from forestry work formed a debris dam upstream of Wairoa that breached during Cyclone Gabrielle. There is also concern that the Waikaremoana hydroelectric scheme discharged additional flow into the Wairoa River catchment contributing to the flooding in February 2023.

This assessment will look at the sources of the woody debris, the likelihood and effect of a debris dam at the rail bridge upstream of Wairoa forming and breaching and the influence the Waikaremoana Power Scheme.

2 WOODY DEBRIS

2.1 SOURCES OF WOOD DEBRIS

Large Woody Debris (LWD) can come from a range of sources during a major flood event. This includes:

Riparian Forests:

- This is the primary source of LWD in most rivers. Riparian forests are the wooded areas bordering rivers and streams. Trees growing along the banks are susceptible to falling into the water due to:
  - Floods/Erosion: Floodwaters can erode the riverbank, causing trees to lose their root support and topple over.[1]
  - Windthrow: Strong winds, especially during storms, can cause trees to uproot and fall into the river.[1,2]
  - Natural Tree Mortality[1]: Trees die from natural causes like disease, insect infestation, or old age. These dead trees are more likely to fall during floods.

Upstream Sources:

- Once moving, woody debris can also be transported downstream[3] from upstream reaches of the river.
  - This can include debris originating from further up in the watershed, tributaries, or even landslides higher in the river system.
  - Major floods (with high water velocity or deep flow) can mobilise LWD from riparian zones[4] upstream and carry them downstream.

Human Activities:

- Human activities can also contribute to woody debris in rivers via several sources:
  - Logging: Improper logging practices near rivers can leave behind stumps or slash (cut branches and debris)[5] that can be washed into the river during floods.
  - Wood Materials: Floatable wooden debris from farmland within the flood plain can also contribute. This includes timber palettes, framing timber, stockpiled firewood, fence posts and other timber structures such as steps, timber bridges or boardwalk.
  - Non-wood materials: Whilst not woody debris, items such as hay bales, plastic drums and other human sourced material that floats can also

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[1] Connecticut Department of Environmental Protection. (2007). Large Woody Debris Fact Sheet. https://portal.ct.gov/-/media/DEEP/fishing/restoration/LargeWoodyDebrisFactSheetpdf.pdf

[2] Broadleaf Tree Surgery LTD. (2023). Why Do Trees Fall Over In A Storm? https://www.broadleaftreesurgery.co.uk/why-do-trees-fall-over-in-a-storm/

[3] Braudrick, C.A. and Grant, G.E. (2001) 'Transport and deposition of large woody debris in streams: A flume experiment', Geomorphology, 41(4), pp. 263–283. doi:10.1016/s0169-555x(01)00058-7.

[4] Piton, G. et al. (2024) 'Large in-stream wood yield during an extreme flood (Storm Alex, October 2020, Roya Valley, France): Estimating the supply, transport, and deposition using GIS', Geomorphology, 446, p. 108981. doi:10.1016/j.geomorph.2023.108981.

[5] Visser, R., Spinelli, R., and Brown, K. (2018). Best practices for reducing harvest residues and mitigating mobilisation of harvest residues in steepland plantation forests. School of Forestry, University of Canterbury

contribute to the debris that can accumulate at bridges and further entangle it.

The frequency and intensity of floods also play a role. More intense floods are more likely to cause bank erosion and mobilize existing woody debris deposits and long periods without large flood events permit revegetation of the riparian margins and flood plain and increase the quantity and size of woody debris available.

Common tree species found in LWD are introduced species such as pine, Poplars, and Willows[6]. Poplars and Willows are commonly found on riverbanks historically planted for riverbank erosion control, and Poplars and pines are planted to help stabilise hillslopes[7] across the catchment, with Pines also planted for commercial forestry, with sources varying from river channel erosion, stored logs in the flood plain, landslides and windfall / slash that can be mobilised by upland tributaries.

Following Cyclone Gabrielle, Hawkes Bay Regional Council (HBRC) commissioned a study into the sources of the LWD across the region[8]. This included a survey of wood at the mouth of the Wairoa River. However, at the time of survey there was nowhere safe to land, so a quantitative assessment was made from above from the Helicopter. The report estimated that the material was 90% pine, 5% willow and 5% poplar, though this was not based on field survey. This report found that, relative to the rest of the region, the LWD in Wairoa had a much larger portion of Pine.

Pieces of pine made up most of the woody debris, with only a small portion of the pine evidencing cut marks. This indicates that most of the pine likely came from landslides and erosion, or was windfall sourced, though some may have been from larger cut material that was broken into smaller pieces. The findings are indicative of large areas of planted pine forest within the catchment on steep erosion prone land, which in some areas enclose the river. The size and depth of the river and limited flood plain also ensures that LWD is transported large distances through the catchment.

The Hawkes Bay Forestry group commissioned Interpine Innovation to conduct a similar study to categorise the LWD volume and portion by species. This included surveying LWD deposits on coastal beaches, river mouths and inland rivers. This study undertook a more in-depth assessment of LWD in the Wairoa catchment and is considered a more robust assessment.

This study also found that minimal amounts of LWD in the Wairoa catchment was harvest slash (2%). However, they observed that the LWD in the Wairoa catchment was primarily a mix of Pine / Conifer (29%), Poplar and Willow (36%) and native (29%). A relatively high proportion of the material was considered aged. Much of this material was likely mobilised from prior stream bank erosion within the catchment.

Strome Advisory, who were engaged by Wairoa District Council to undertake an independent review, also noted that much of the LWD at the rail bridge was poplar in

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[6] Interpine Innovation. (2023). Cyclone Gabrielle Post Event Woody Debris Assessment – Hawke's Bay. https://www.hbforestrygroup.co.nz/wp-content/uploads/2023/04/Cyclone-Gabrielle-Post-Event-Woody-Debris-Assessment-Hawkes-Bay-2023-2.pdf

[7] Northland Regional Council. (2007). Poplars and willows for soil conservation. https://www.nrc.govt.nz/resource-library-summary/publications/land/poplars-and-willows-for-soil-conservation/poplars-and-willows-for-soil-conservation/

[8] Roper, M. (2023). Cyclone Gabrielle Woody Debris Species Composition Assessment. https://www.hbrc.govt.nz/assets/Document-Library/Cyclone-Gabrielle/Post-Cyclone-Gabrielle-2023-large-woody-debris-assessment-31.03.2023-FINAL-v1.pdf

origin and was likely sourced from stream bank erosion, and ironically, had likely been planted along riverbanks to prevent erosion.

The studies are consistent in their conclusions that a large portion of the LWD deposited throughout Hawkes Bay did not originate from the harvest of plantation forests, though pine plantations in general did contribute (varying estimates) through windfall, riparian erosion, and slope failures.

Figure 1 – LWD forming a line along the Wairoa River – this line typically follows the deepest part of the channel.

Figure 2 – Woody debris accumulated post cyclone along the river margin. The largest material appears to be Poplar.

2.2 DEBRIS AT THE RAIL BRIDGE

LWD is a serious issue for bridges. The debris becomes trapped on the bridge piers forming 'debris rafts'. This increases the potential for scour under the bridge, increases lateral loading on the structure, reduces capacity through the bridge and raises upstream flood levels.

If the river level exceeds the underside of the bridge, a much larger 'matt' of debris can also form which can further restrict flow under the bridge.

Figure 3 – Awatoto River Bridge, Image courtesy of HBRC

Figure 4 – Debris matt against the Ashburton River Bridge, Canterbury

In the case of Wairoa, the PNGL rail bridge upstream of the town trapped a large amount of LWD which was pushed up onto the deck of the structure (see Figure 5). Some of the Wairoa community believe that this bridge formed a 'dam of debris' which then breached and released a surge of flood water. There is certainly evidence that the rail embankment at the bridge approach was washed out and failed, so such a scenario is plausible.

However, what is not understood is the likely the scale of such a breach here and how much it might have contributed to the flooding in North Clyde.

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Figure 5 – Debris on the PNGL rail bridge. Image courtesy of HBRC.

To test the potential impact of a breach and / or sudden debris clearance, a model scenario was developed where the bridge was partially blocked with a 2m thick debris matt and 50% overall debris blockage. Around the peak of the flood, the simulated debris blockage was removed and 200 m of rail embankment east of the bridge lowered to simulate a sudden release of impounded flood water.

The results of this assessment indicated that such a breach could have a notable effect on the flood flow entering North Clyde. Flow out of the Wairoa River into North Clyde was simulated to increase from approximately 800 m^3/s to 1010 m^3/s. However, the corresponding flood elevation did not change significantly with this flow increase, with the additional pulse of flow increasing the flood elevation only in the order of 0.09 m.

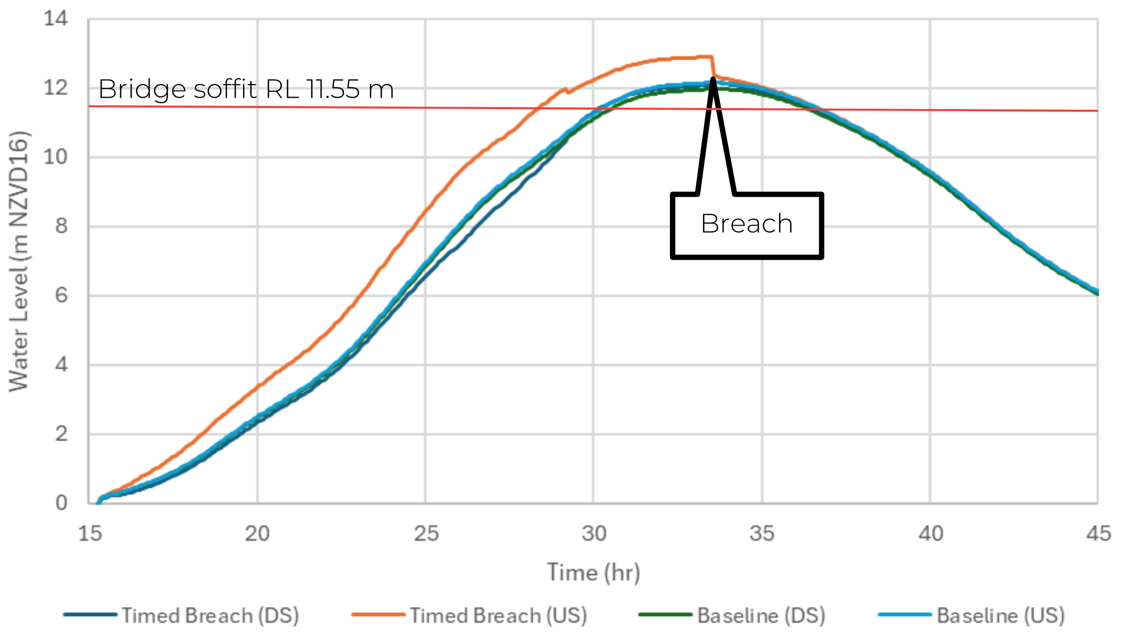

Figure 6 – Predicted water level at the rail bridge for the breach scenario ('Time Breach') and without a breach ('Baseline').

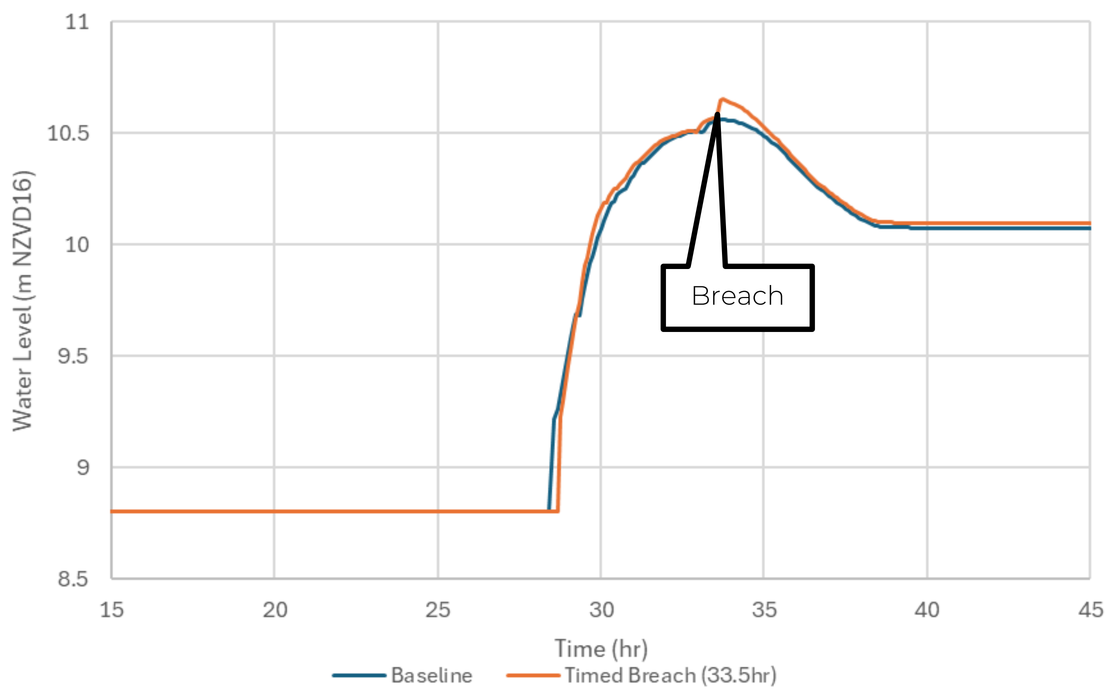

Figure 7 - Predicted water level in North Clyde for the breach scenario ('Time Breach') and without a breach ('Baseline').

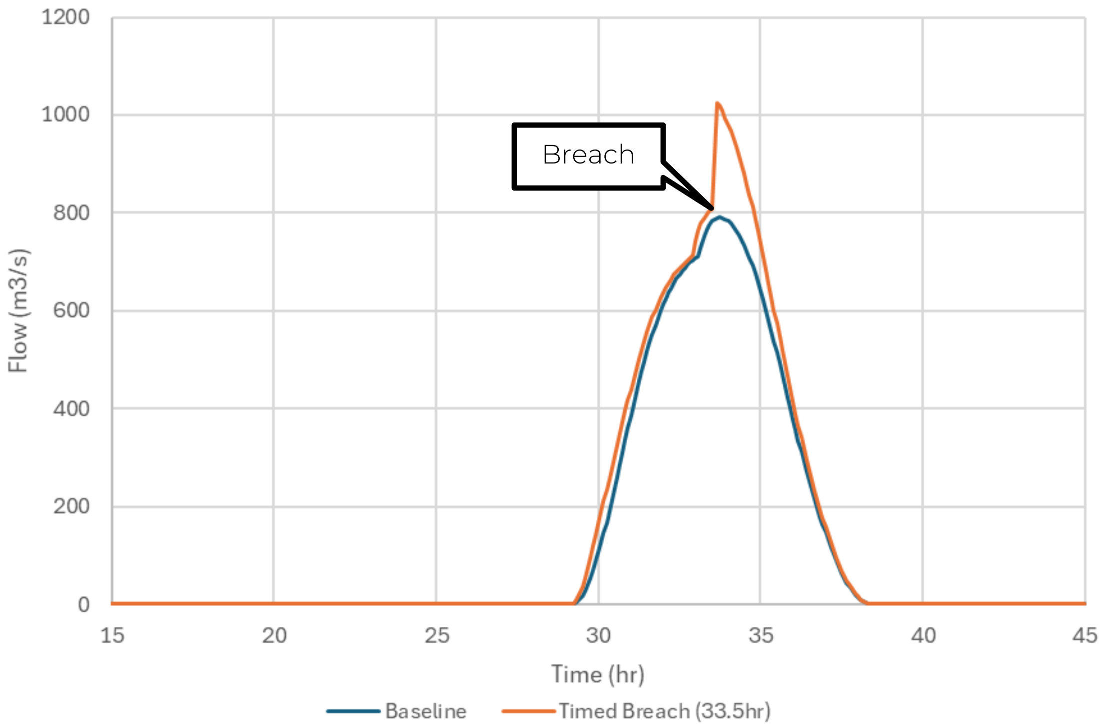

Figure 8 - Predicted flow into North Clyde for the breach scenario ('Timed Breach') and without a breach ('Baseline').

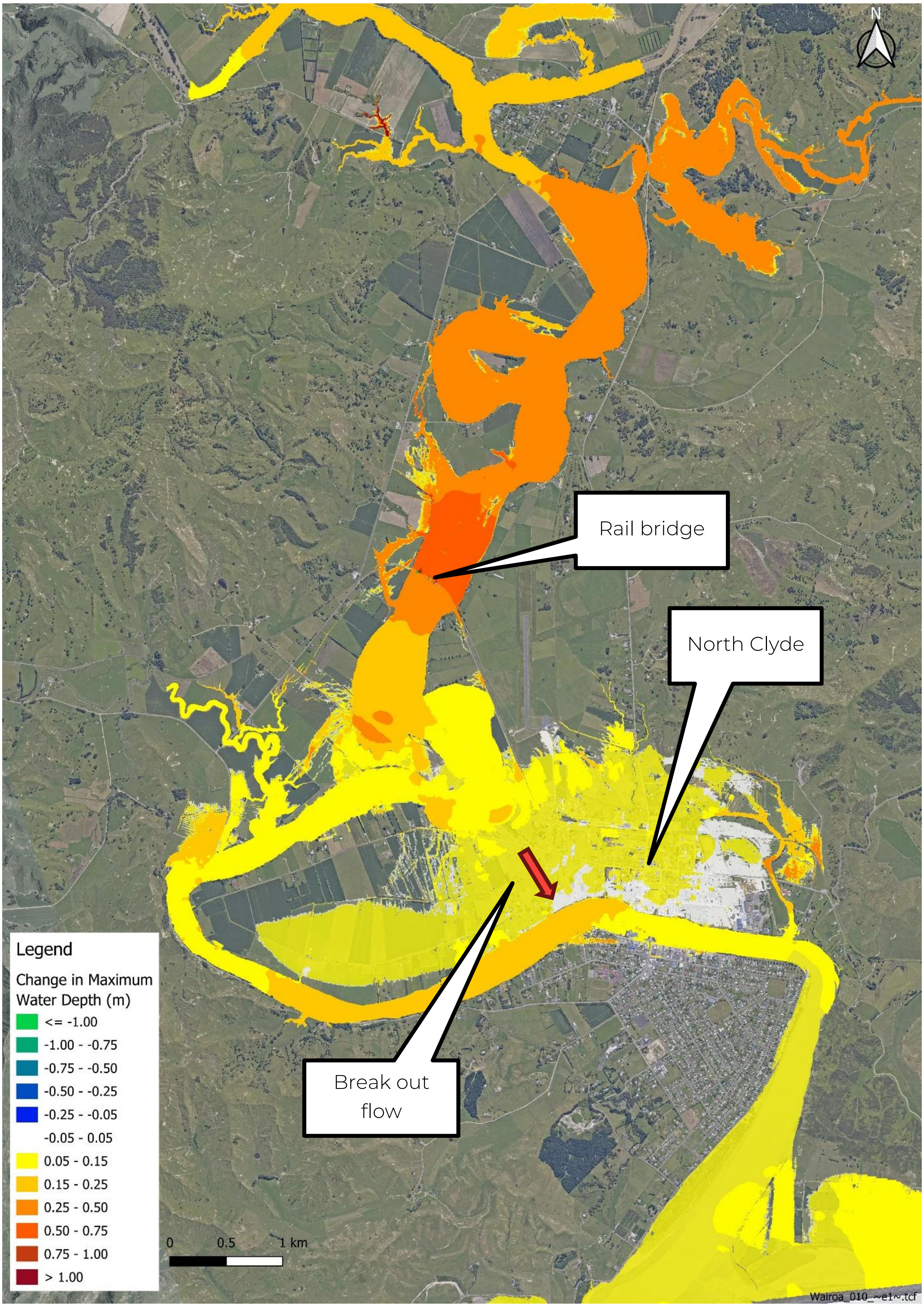

Figure 9 – Change in flood depth for the breach scenario versus no breach.

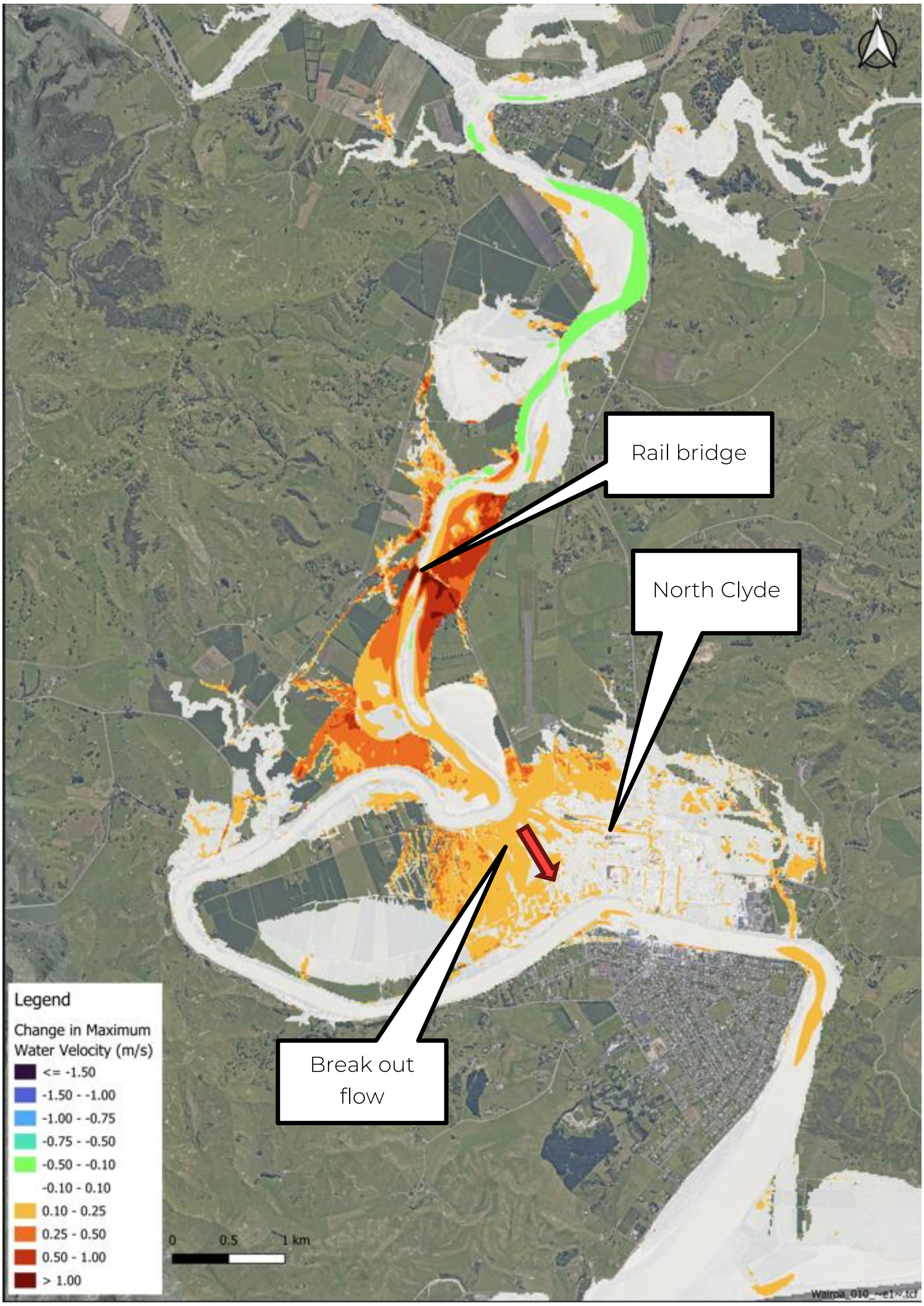

Figure 10 - Change in velocity for the breach scenario versus no breach.

The flood modelling indicates that the bridge could have caused a sudden release of water. However, by the time this ‘pulse’ of water enters North Clyde its scale would be greatly diminished. This is due to the width of the flood plain and flood storage between the two locations. It may have contributed to the flooding in North Clyde, increasing the flood depth by around 90 mm and velocity <0.25 m/s. However, without a breach, North Clyde would have still flooded, and the scale of the pulse predicted is too small to explain all the flooding observed on its own. Such a breach would also need to occur close to the peak of the flooding to have exacerbated the flooding in North Clyde as predicted here.

However, a sudden release of impounded water at the rail bridge, or upstream, is not supported by the level data recorded by HBRC at the rail bridge which is considered reliable. The observed level data does not show a sudden drop or increase in the upstream water level that would be commensurate with a sudden or rapid release of water (at least not within the frequency of observations) that would be indicative of a rapid release of water. If a sudden release of water had of occurred at the rail bridge, you would expect to see a sudden drop in water elevation upstream of the bridge (the location measured by the gauge) as indicated in Figure 6.

Lastly, it should also be noted that it also plausible debris at the bridge slightly reduced the peak flood flow by restricting flow and utilising greater flood storage upstream.

So, in summary, had a sudden breach of accumulated LWD occurred at the peak of the flood, it would have contributed to flooding in North Clyde in a relatively minor way. If a sudden or rapid breach occurred, we would expect to see a commensurate drop in river level at the HBRC level gauge. The gauge though, which is considered reliable, did not record such an event. Hence the breach of the bridge approach likely occurred over a prolonged time-period and did not release a sudden pulse of impounded flood water.

3 LAKE WAIKAREMOANA HYDROELECTRIC SCHEME

Strome Advisory Ltd, engaged by Wairoa District Council (WDC) undertook an independent review of the hydro-schemes operation during Cyclone Gabrielle. This followed a joint statement from Genesis and HBRC that made clear the flows discharged from the scheme were in the order of 40 m^3/s, in line with the schemes consented discharge conditions and that the level of the lake was lowered in advance of Cyclone Gabrielle to provide additional flood storage. Genesis has also commissioned an independent hydrological audit by SLR of its flow management during the cyclone[9].

The SLR audit validated the joint statement made by Genesis and HBRC and noted that the dam's spillway never functioned. Stone Advisory Ltd in their independent review also noted this is supported by the fact that the spillway is still covered with vegetation which would have been removed had it operated. This means that the discharge was limited to only the schemes flow controlled piped outlets.

Strome Advisory Ltd also noted that the more significant flood flows originated from the northern part of the Wairoa catchment, as supported by rain gauge and river flow data, rather than the Waiau catchment.

In terms of the flooding in North Clyde, it appears that the Lake Waikaremoana Power Scheme did not contribute any additional flow into the Wairoa catchment, and in fact likely reduced the peak flow that would have otherwise occurred by attenuating run-off from the upstream lake's catchment.

Lastly, it should also be noted that flood flows from the Waiau Catchment tend to lag flows in the main Wairoa River forming a secondary smaller peak. Typically, this delay is around 2-2.5 hours and rather than elevate the peak flood flow, it acts to extend the duration. In the case of Cyclone Gabrielle, the scale of the flood event calculated for the Waiau catchment was lower than that in the main Wairoa catchment confirming Strome Advisory Ltd's conclusion that the larger portion of the flood flows came from the northern catchment.

[9] Waikaremoana Power Scheme Hydrological Audit 28 August 2023, SLR

4 FLOOD PLAIN COMPLEXITY

The surges of flow that were reportedly experienced by the community may have been caused by more conventional means. As the land falls toward the coast, flooding enters this area rapidly and flows across it at speed. This is because the North Clyde area is effectively a secondary flow path of the Wairoa River during significant flood events.

During a major flood event, the river surface level is not static and will pulse due to turbulence, debris build up along the banks and wind action. Flow entering North Clyde over the river's bank, which effectively acts as a weir, would be sensitive to small variations in river level, creating pulses of flow. When combined with the complexities of a rural – urban flood plain this would further complicate the movement of water, with structures such a collapsing fence forming sudden pulses of flood water and causing water to move in directions that might appear unnatural.

Given there was no sudden drop in river elevation at the PNGL rail bridge or any overflow at the Waikaremoana Power Scheme, we consider this as the most plausible cause of any sudden surges of water experienced by the community.

Figure 11 – a fence covered with flood debris or 'wrack' (Wairoa). Such structures can influence how flood waters move through an area.

Figure 12 – a fence flattened by the force of water (Wairoa) – such failures can create sudden surges of flood water.

5 SUMMARY OF FINDINGS

There was a substantial amount of LWD in the Wairoa River, as occurred across the region, and its effect was evident on the bridges upstream of Wairoa. The LWD was likely a mix of Poplar, Pine, native timber, and Willow, with riparian erosion and slope failures being the main source of large material. In the case of the PNGL rail bridge, this LWD would have increased the upstream flood level and contributed to the failure of the approach embankment.

However, the rate / timing at which this failed was unlikely to have created a significant release of impounded flood water or contributed in any significant way to the flooding in Wairoa.
The operation of the upstream power scheme also does not appear to have contributed to the flooding in Wairoa and may have somewhat reduced it by attenuating the upstream flows through the lake.

This does not mean that community members who experienced a sudden release of water were mistaken. It is likely that sudden surges of water were experienced in North Clyde by residents. This is due to the nature in which the area flooded. As the land falls toward the coast, flooding enters this area quickly and flows across it at speed. The North Clyde area is effectively a secondary flow path of the Wairoa River during significant flood events.

Water overtopping the banks would likely have pulsed due to turbulence in the main river and the complexities of a rural – urban flood plain would have further complicated the movement of water, with structures such a collapsing fence forming sudden pulses of flood water.

For those not familiar with large flood events and river hydraulics, the speed at which the flood water can rise can be alarming and seem almost un-natural. Our conclusion is that the flooding was primarily caused by the significant rainfall that fell across the catchment combined with the antecedent weather of the 2022-2023 period. The sudden onset of the flooding through North Clyde was due to the area forming a secondary flow path of the river that falls toward the coastline. The loss of the rail bridge approach may have contributed in some way to the flooding, but not in any significant way. If the rail embankment had not breached, the area would have still flooded.

6 LIMITATIONS

This report ('**Report**') has been prepared by WSP exclusively for Hawke's Bay Regional Council ('**Client**') in relation to testing the feasibility of the flood protection options for Wairoa ('**Purpose**') and in accordance with the proposal 'Scope – Slash' dated 21/07/2023. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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