Wairoa Cyclone Gabrielle Review

Prepared for – Wairoa District Council

APRIL 4, 2024

Disclaimer

Whilst every effort has been made to ensure the information in this document is accurate, no responsibility or liability is accepted for any error of fact, omission, interpretation or opinion that may be present, nor for the consequences of any decisions based on this information.

Acknowledgements

This findings in this review have been made possible through the constructive and open comments and contributions provided by leaders and affected people within the Wairoa Community, Wairoa District Council, key staff from Hawke's Bay Regional Council, the Forest Industry and Genesis Energy Limited.

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Glossary

- **ARI** – Annual Recurrence Interval - Average time in years between floods of this size hence the expression 1 in 100 floods
- **ANTECEDENT**– conditions pre an event
- **CUMECS** – Cubic metres per second flowing past a given point.
- **WOODY DEBRIS** – Mix of part trees, whole trees, slash, fence posts, etc.
- **SLASH** – Sawn material post-harvest, typically left on forest site.
- **FIELD CAPACITY** – A measure of soil moisture whereby soils have no retention capacity left.
- **CLASS VI** & **VII LAND** - Land classifications derived from a system called the New Zealand Land Resources Inventory (NZLRI) – depicting tiers of productivity based on soils/topography/erosion susceptibility.
- **LIDAR** – Light Detection and Ranging – an extremely high accuracy method of measuring topography – now down to centimetres.
- **HBRC** – Hawke's Bay Regional Council
- **WDC** – Wairoa District Council
- **WSP** – Engineering Consulting Group undertaking flood infrastructure design options for Wairoa on behalf of HBRC.
- **HBFG** – Hawke's Bay Forestry Group

Executive Summary

Cyclone Gabrielle and its flooding within the Wairoa Catchment, the causes and consequences still dominate local sentiment over a year after the event. This review will hopefully play a part in improving community, businesses and governing institutions understanding of what has and has not driven the flooding and resolve some of the enduring uncertainties. Success in this objective would be defined by attention and energy being directed toward actions that further aid recovery and reduce risks when similar circumstances arise in the future – as they will inevitably do!

The approach taken through this review has been as follows:

- Form a team of experts with the technical skill sets necessary and an understanding of the Wairoa Catchment.
- Undertake visits to relevant sites within the catchment,
- Meet with a wide range of local people and organisations.

This process has led to the formation of an initial view on the issues which have then been:

- Tested against relevant data including flood and rainfall statistics.
- Where necessary feedback from the organisation's responsible for generation of that data has been obtained.
- The final step has been to have this document peer reviewed.

The most important observation arising from this review is that a combination of extreme soil moisture saturation, coupled with the potential for a major/extreme storm event, typically ex tropical cyclones, should be considered a high to very high-risk scenario for damaging flooding. This is not a new view as it was highlighted in an HBRC flood risk analysis conducted in 1994.

The nature, shape, and high-volume short run rivers of and within the catchment means that the Wairoa Flood plain and the township are highly exposed to extreme flooding.

Forward warning of flooding that will affect areas such as North Clyde should now be predictable, especially as the data set around flooding events has materially improved over the past 30 years. However, times for action will be very short. To deliver timely warning communication systems that enable a rapid community response needs serious attention.

By contrast there is very good local knowledge of regularly reoccurring flood risk issues such as closure of the Wairoa River mouth. This expertise should be both actively utilised and trusted.

In terms of mitigating flood risk of both urban areas and infrastructure – there is not one 'silver bullet.' Whilst it is not this review's remit to explore mitigation measures in detail some issues and actions are clear.

In improving urban community resilience and given the strong cultural affiliation tangata whenua have with living in North Clyde more than one intervention should be considered – i.e. flood protection infrastructure – flood spillways/flood banks could be coupled with consideration of lifting houses above the inundation level.

Risks to infrastructure such as bridges from woody debris dams is not new. There are a variety of contributing sources of material with large riverbank poplar trees arguably being the primary risk due to scale. Risk is quite likely to have reduced along the Hangaroa/Wairoa Tributary – given removal of many of these trees, however it remains an issue in the Waiau tributary. A further issue post Cyclone Gabrielle is the spread of plant material which is regrowing extremely rapidly.

Much of the woody debris attention is focused on radiata pine plantations especially harvest slash – but Gabrielle has clearly indicated that very intense rainfall – plus 500 mms over 12-18 hour periods will drive whole tree failure especially on very highly erodible land -this subject should be given some dedicated attention as it may well prove to be a bigger risk issue than harvest slash in the context of infrastructure risk.

In periods of extremely high stress as was the case throughout and post Gabrielle, localised issues such as flooding of Lake Waikaremoana and downstream of the Waikaremoana Hydroelectric scheme may be conflated with unrelated issues such as flooding of North Clyde. To avoid this, it's critical that there's a clear understanding about what the scheme can and can't do. The Genesis team's interaction with the Mayor of Wairoa and this review has been a positive initiative.

Part of what has driven this work has been the sense of isolation that the Wairoa community feels it has from the balance of Hawke's Bay. Whilst – again this is not a new issue the stress of Gabrielle has exacerbated it. The visible sign of attention in the community around flood risk response is the current presence of WSP with their options and design work on flood mitigation options but once WSP have finished their work they'll be gone. Whilst there been an exchange of letters between governors of WDC and HBRC, key HBRC technical experts have not been visible in the community. Having key technical people present on ocassion may help to build confidence and bridge this issue.

As a final comment all parties who have contributed directly to this review have done so in a positive and constructive manner. This affirms that events such as Gabrielle adversely affect everyone concerned, albeit some to a much larger degree than others. The main sentiment detected through this process has been how can we learn from Gabrielle. In this spirit a collective response is ultimately the best way forward.

Section 1 | Independent Review Purpose

To ensure there is a robust 'on the ground assessment' of the local factors involved in driving and/or contributing to flooding of the Wairoa Region, particularly the area of North Clyde.

The local knowledge and understanding of the event are clearly documented in a way that ensures the local voice and expertise is heard and utilised in consideration of future flood management practices and decisions for the Wairoa Catchment.

The scope of work for this independent review includes the following;

1) Develop a view on the significance of the Cyclone Gabrielle Flood event in comparison with the Cyclone Bola Event
2) Comment briefly on flood mitigation measures adopted post Cyclone Bola- 1988.
3) Confirm the Hawke's Bay Regional Council's findings as per Dr Nic Peet's memo of 4th September 2023, '*Wairoa Rainfall and River Flows in Cyclone Gabrielle*'.
4) Obtain and review rainfall and river flow data for subsequent significant rainfall events post Gabrielle and their consequences, if any.
5) Consider additional factors that may have contributed to the flooding of Wairoa during Cyclone Gabrielle including, but not limited to:
    a. Impacts of woody debris including its origin and extent
    b. Validation of Genesis Energy hydrology data
    c. The potential impacts of wood debris dams on infrastructure (such as bridges).
6) Comment briefly on the relevance of the findings for proposed future interventions including flood management infrastructure and regulatory interventions.

Inclusions and Exclusions

The Wairoa Catchment in its entire extent, across both the Wairoa and Gisborne Districts, is the primary focus.

Flood risk issues beyond Gabrielle within the Wairoa Catchment are in frame.

Flooding issues/infrastructure damage/landscape damage, including in forests and farms, outside of the Wairoa Catchment but inside of the Wairoa District and or adjacent to the district are out of frame. Occasional exceptions are where information is used for enabling contextual and comparative commentary in relation to the Wairoa Catchment itself.

Civil Defence actions and initiatives are not part of this review.

Solutions to the issues arising from this review are in frame to a limited degree. It is not the remit of this work to comment on the flood mitigation solutions being developed through the Tripartite process involving HBRC/WDC/Tatau Tatau o Te Wairoa. However, where it is evident

that there are issues, and or practices, identified through this review where positive actions or adjustments may benefit, brief comments are made.

Section 2 | Review Method

Written responses to questions were provided to Wairoa District Council by the Hawke's Bay Regional Council (HBRC) on 9 and 23 June 2023, following the WDC mayor's request for information on 16 March 2023, concerning causes of flooding arising from ex Tropical Cyclone Gabrielle. The HBRC response was largely founded on an analysis of its rainfall and river flow data. This review seeks to add more definitive local context and depth to the subject. The review has been conducted as follows:

Formation of an expert team with both relevant technical knowledge of issues and drivers associated with large scale flooding events and a sound knowledge of the Wairoa Catchment itself.

This Team includes;

Andrew Newman – Review Lead – background in land management, forestry science, water resources, infrastructure and agribusiness, and ex CEO of HBRC 2007 –2013, 2016 – 2017.

Mike Adye - Civil Engineer - ex Group Manager, Asset Management, Hawke's Bay Regional Council 1993-2017.

Peter Manson – AgFirst – ex Land Management, HBRC in Wairoa 1985 – 2022.

Brett Gilmore – Brett Gilmore Consulting - 35 Years in Forest Industry including 10 years with PanPac Forest Products in Hawke's Bay 2007-2017. Forester of the Year, NZ Institute of Forestry 2012.

Peer Review

Graeme Hansen – Peer Reviewer – ex Group Manager, Asset Management, River Engineer with HBRC 1978 - 2018

Meeting with key Local People

Within the Wairoa District and beyond and discussing Cyclone Gabrielle and where relevant other flood event issues for Wairoa – a full list is in attachment 1.

Catchment and key site visits

Team members and key local people undertook tours of the catchment and key sites. This included 5 trips around the catchment including critical sub-catchments/the Wairoa River mouth and to key infrastructure sites. A further trip by helicopter was undertaken from the Waikare Catchment on the District Boundary across the key plantation forestry sites within the Wairoa Catchment and Wairoa District.

Review of Key Documents

1. Preceding and post Gabrielle detailing issues including:

(See attachment 2 – list of references)

   a. Previous flood event analysis – undertaken by HBRC on the 1948 flood event and ex tropical Cyclone Bola 1988.
   b. HBRC technical reports covering Wairoa Catchment Flood Modelling and Riverbank Erosion, and Council reports covering flood risk mitigation options both around the township and at the Wairoa River mouth.
   c. Woody Debris Surveys post Gabrielle undertaken by
      i. Eco Solutions on behalf of HBRC by air and on the ground in most but not all cases, and
      ii. Interpine on behalf of the Hawke's Bay Forestry Group by physical measurement of composition and volume on the ground.
   d. Documents submitted to various post Gabrielle Inquiries – including the Government Inquiry into the North Island Severe Weather Events, and to HBRC's own Independent Review of the Performance of HBRC's Flood Scheme Assets and River Management Programmes in Response to Cyclone Gabrielle
   e. Outrage to Optimism - Ministerial Inquiry into land uses associated with the mobilisation of woody debris (including forestry slash) and sediment in the Tairawhiti/Gisborne District and Wairoa District.
   f. An independent Hydrological Audit undertaken for Genesis Energy Ltd by SLR Consulting LTD. on the Waikaremoana Power Scheme covering the period from November 2022 through Gabrielle. This covers both Tropical Cyclones Hale and Gabrielle focusing on a high-level hydrological overview. This includes consent conditions and compliance, plant status, a detailed hydrological review in the days prior to Gabrielle, and a detailed review of the hydrological response to Gabrielle during the event including compliance with consents. A comparison is made of flows immediately downstream of the scheme with flows elsewhere in the Catchment.
   g. NIWA's Extreme Value Analysis of Tropical Cyclone Gabrielle Flood Flows in Hawke's Bay Region, February 2023.
   h. Various correspondence with HBRC.

2. Review of the HBRC's river flow and Hydrological data – this has been undertaken **not as a technical audit but rather to validate or otherwise** the picture of the Gabrielle Event and its impact that has been built 'bottom up' through the 'on the ground' process above. Where there are points of detail that need further advice, a list of questions has been submitted to HBRC – see Attachment 4.

3. The result of these steps has been to create a 'picture of Gabrielle and its impact which is plausible, that is preferably easily understood by a non-technical audience and people directly affected, which in turn is supported by technical evidence.

4. This has then been tested with Wairoa community representatives, adjusted where there are clear errors or omissions and peer reviewed.

Note – the following limitations apply

The review has relied on evidence in the landscape one year after the primary event, alongside people's recollections one year after the event. The bulk of the technical data has been derived from HBRC, the Forest Industry and the Independent Audit of the Waikaremoana Hydroelectric scheme, leading up to and through Cyclone Gabrielle. The data is generally considered of good quality by the review team. Where there are exceptions to this they are identified in specific comment.

Section 3 | Wairoa Catchment Described

The Wairoa Catchment is 3563 square kilometres and ranges in altitude from sea level to approximately 1,300 metres above sea level. The catchment shape is unique in a New Zealand context being like a 'half circle' for much of its extent. This issue is relevant when considering the timing and coincidence of water contributing from the various sub-catchments. All major tributaries converge into one main stem, the Wairoa River, at the start of a 3,000-hectare, flood plain. The tributaries and the Wairoa River are steep and a short run of approximately 40 - 70 kilometres whereas the flood plain has a very gradual fall to the sea.

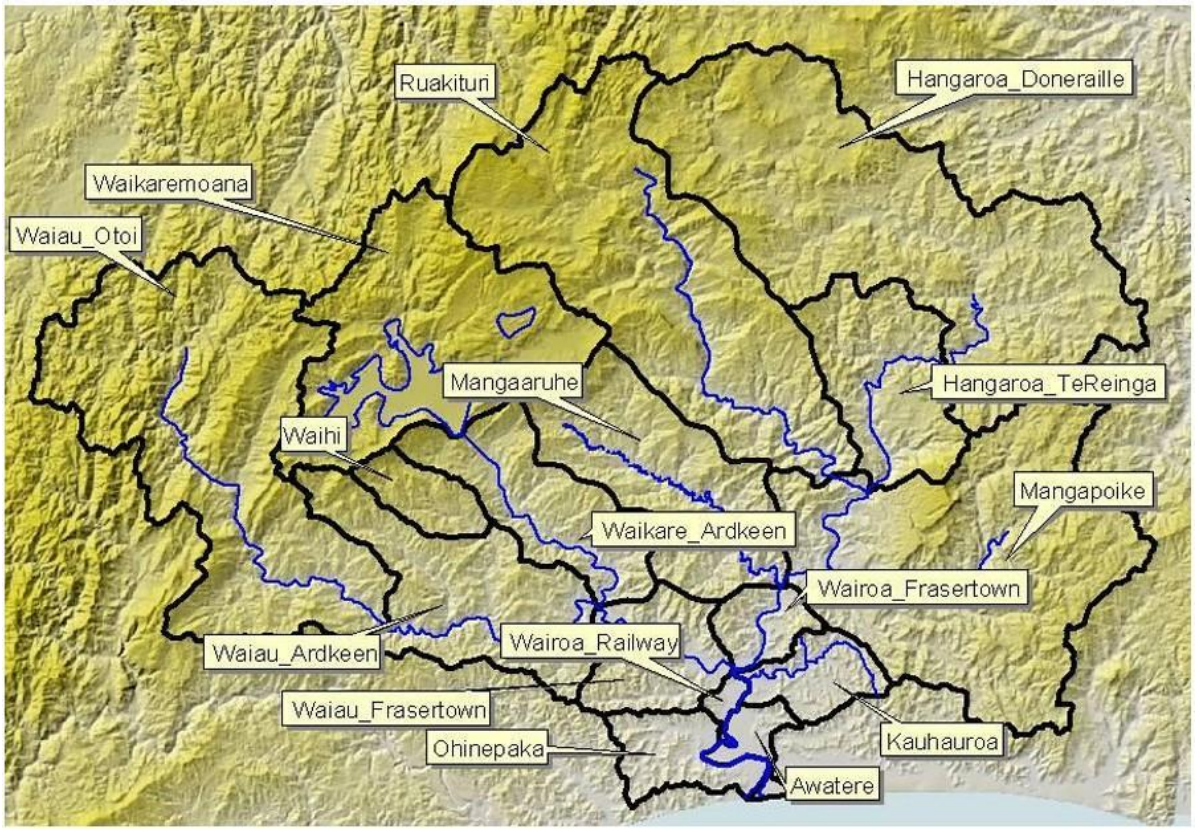


Figure 1. Wairoa Catchment Map

The geology of the catchment is primarily sedimentary sandstone and silt stone with a limited amount of older argillite and greywacke in the far west of the Waiau sub-catchment. There are some areas where pumice and ash overlie the sedimentary material. Given the fragile underlying geology the Wairoa River carries large volumes of silt, as do the tributaries. Soil moisture retention capacity in much of the catchments hill country is low due to the very thin soils on class VI and VII land[1].

[1] Class 6 & 7 land is typically hard to very hard hill country with varying levels of erosion susceptibility.

Of the 3 main land cover types, approximately 40% is native forest, 45% exotic grassland, 12/13% plantation forestry (this maybe slightly higher with the emergence of carbon forests), with the balance being grassland in pastoral hill country.

The small urban settlement of Wairoa is located on the flood plain on either side of the Wairoa River close to the river mouth.

The Catchment is prone to frequent flooding and carries large volumes of water in comparison to other major Hawke's Bay rivers. Flood flow analysis data from NIWA suggest the flood flows in the Wairoa catchment throughout Gabrielle were some of the highest of any Hawke's Bay River.

According to flood modelling by HBRC in 2006, a 1 in 20-year flood event is capable of flooding parts of the flood plain. A report produced in 1994 rated the cyclone Bola Flood as a 1 in 30-year event. Additionally, the risks arising from flood events to the Wairoa River are significantly compounded by the state of the bar at the river mouth which is either frequently closed or has the opening located well south or north of the main stem.

Insight

In summary the key issues that contribute to the Catchment's vulnerability to floods and their effects include its shape, river gradients, the geology, soil moisture retention capacity or lack thereof, the convergence of all tributaries into a single stem, and the condition and position of the bar at the river mouth.

Section 4 | History of flooding major/high profile and or documented flooding events within the Wairoa Catchment

Event date	Weather event type	Pre-conditions (antecedent)	Scale in flows	Key sub catchment contribution	Woody debris/ silt	Consequences
May 1948	Depression	Wet year preceding	8,200 cumecs +/- 35%	Considered a 1 in 15-year rainfall event but a 1 in 100 flood event[2]	Reports of significant woody debris Significant deposits of silt in township	Flooding of North Clyde and Marine Parade/ Awamate
March 1988	Tropical Cyclone Bola	Dry/normal year preceding	5,000 cumecs +/- 34%	Rainfall extensive across catchment over 3–4-day period Considered a 1 in 30-year event[3]	Reports of significant woody debris	Destruction of Wairoa Bridge Some minor flooding in North Clyde, Marine Parade
February 2023	Tropical Cyclone Gabrielle	Abnormally Wet year preceding – see figure 2. below	6,200 cumecs – preliminary noting measure peak flows – Marumaru of 4,100 cumecs Waiau Ardkeen 1656 cumecs[4]	Hangaroa/ Wairoa/ Mangapoike dominant Significant rainfall in Hangaroa and Mangapoike in particular	Significant woody debris – evident Significant deposits of silt in North Clyde and on some farms/racecourse adjacent to township	Flooding of North Clyde Farms – south side of river – opp Frasertown Awamate

Table 1. Major flooding events

A brief history of flood risk mitigation analyses and initiatives in the Wairoa Catchment

[2] Wairoa Flood Protection, Agenda item 10, 24 February 1999, Hawke's Bay Regional Council

[3] Wairoa Floodplain Management Plan, Progress report July 1994, Hawke's Bay Regional Council

[4] Variously sourced from correspondence between A Newman and HBRC 6 March 2024, NIWA 'Extreme Value Analysis during ex Cyclone Gabrielle 23 February 2024 & Waikaremoana Power Scheme, Hydrological Audit, SLR Consulting NZ Ltd, 28 August 2023- data supplied by HBRC – subsequently described as preliminary, correspondence.

The 'Esk Valley Storm' of April 1938 is credited with being a trigger for the establishment of the Soil Conservation and Rivers Control Act, 1941 and the establishment of Catchment Boards and Commissions.

The Hawke's Bay Catchment Board and Regional Water Board was constituted in September 1943.

Activities in the Wairoa Catchment undertaken by the Catchment Board included soil conservation works on erodible Hill Country and Riverbank stabilisation works including tree planting (poplars and willows) and the establishment and operation of drainage schemes including Ohuia/Whakaki in 1966 and Paeroa in 1958. The early catchment board planting on/or adjacent to rivers and subsequent tree spread has now become an issue under flood conditions providing a major source of woody debris including very large whole trees, in particular poplars, into the river systems.

Post Bola in 1988, flood modelling and flood warning systems were upgraded, and the number of weather stations increased from 3 to 16 and an expansion to 10 flow monitoring sites. One weather station, Doneraille Park, provides monitoring data on average daily soil moisture which is relevant for monitoring antecedent conditions ahead of weather events. The investment in the additional sites and flood warning system was made to explicitly enable early warning for flood risk, enabling proactive civil defence evacuation of at-risk residents.

Significant technical work was undertaken on flood protection options for the Wairoa Township by HBRC between 1994 – 2000 including assessment of riverbank risks, stop bank options, and river mouth management options. None of the hard infrastructure options were progressed in part due to complexity, cost, community affordability (noting that the government suspensory loans, which had 75% funded the Heretaunga Plains and Upper Tukituki schemes, were no longer available). In the case of infrastructure for managing the location of the river mouth, there was uncertainty over likelihood or otherwise of success.

Allied with this, HBRC established a Wairoa Northern Rivers and Streams Scheme and retained a special Wairoa Flood Reserve initially created out of a special Napier Port Dividend and general funds. The scheme has funded work on willow and poplar removal for the past 20 years, primarily on smaller tributary streams. Between the Scheme and the reserve, HBRC is indicating the funds available are very limited- approximately $200,000[5].

HBRC developed a flood model for the Wairoa River catchment in the early 1990's and this has been progressively upgraded as new and more accurate information has become available over time. Improvements were made in 2006, based on Lidar data from 2003 and further post Gabrielle Cyclone based on a fresh Lidar survey in 2020.

[5] Email communications Matt McGrath/Andrew Newman 7 March 2024

Section 5 | Underlying Issues which influence and or exacerbate flood flows and their effects pre- and post-Gabrielle

Issue 1 | Antecedent climatic conditions

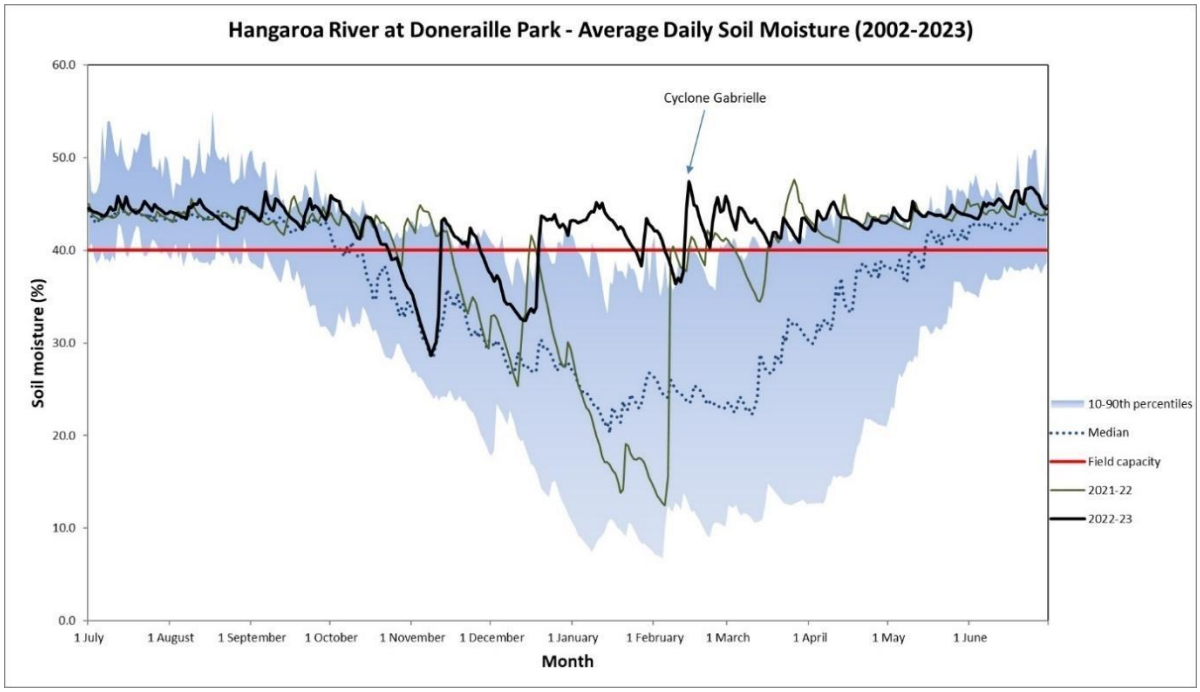


Figure 2. Soil Moisture Conditions

Immediately prior to Gabrielle, in a period extending from late December 2022 to February 2023, soil moisture conditions, measured at Doneraille Park, were largely well above what is considered 'field capacity'. This is consistent with the wetter than usual conditions a La Niña climatic pattern can bring, and it is reasonable to assume that the conditions extended over all the Wairoa catchment. It is important to note that the rainfall for the 2023 year was approximately 150% of the long-term average. The significance of these conditions is well described in the Wairoa Flood Plain Management report, July 1994. In simple terms, a saturated catchment will have a major influence on the scale of flood flows, and their velocity in a storm event. In addition, the very thin soil cover in class VI and VII land throughout the catchment exacerbates this risk.

Insight

In La Niña type years, flood risk levels will dramatically increase for the Wairoa Catchment. Arguably the current flood risk awareness within the community has been primarily focused on the possibility of ex-tropical cyclones arriving and in the case of Wairoa whether the river mouth is open or closed,

and/or in an optimal or sub-optimal position. Awareness of soil moisture conditions ahead for storm events should be a critical indicator of the need for flood preparedness.

Issue 2 | Incidence of woody debris/forestry slash entering water ways and either diverting flows, damaging infrastructure, or reducing amenity values

Woody debris damage issues within the Wairoa Catchment

Wairoa District Council (WDC) note the following: the Ruakituri Bridge sustained damage to piers as a consequence of woody debris blockages in a storm in March 2022. Subsequent woody debris blockages in Gabrielle 'finished the job'[6]. A woody debris dam formed during Gabrielle, behind the Kotare Bridge, resulted in scouring at the northern end of the bridge abutment. A woody debris dam behind the Wairoa Rail bridge affected flood flows within the Wairoa mainstem, and woody debris volumes deposited at the river mouth are significant and long lasting.

Sources and composition

There are three primary sources of woody debris including native forests, radiata pine plantations, and trees adjacent to rivers and streams (typically poplar and willow). All major recorded floods have noted the incidence of woody debris adversely affecting infrastructure, particularly bridges during flood events, however the composition has changed over time.

[6] Michael Hardie WDC Engineer

Figure 3. Woody Debris Wairoa Bridge 1948

Figure 4. & 5. Woody Debris Wairoa River Mouth, March 2023

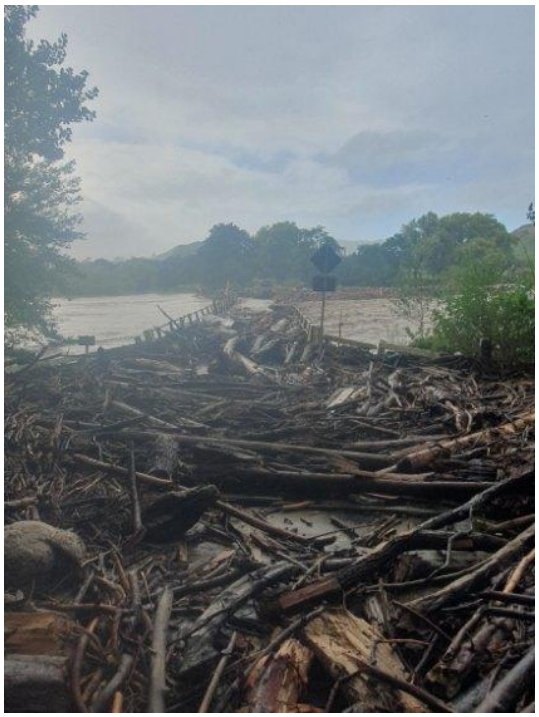


Figure 6. Woody Debris Riverina Bridge, Wairoa River, Marumaru approx 7am February 14, 2023

Figure 7. Woody Debris Kotare Bridge, February 2023 mainly pine but not physically surveyed

As noted in section 3 above, the Wairoa Catchment land cover comprises native forest, grassland, and pine plantations in order of scale. Land use change in the catchment over the past century has cycled through.

- Native forest clearance for pastoral farming,
- Some limited tree establishment for soil conservation purposes from the 1950's onwards on pastoral land and adjacent to rivers and streams, and
- Over predominantly the last 30 years, conversion of pastoral farmland to plantation forests. Of significance is that many of these forests are either being harvested or due for harvest, within their first rotation.

The incidence of woody debris post Gabrielle has received significant attention from the public, the forest industry, HBRC and in this review.

As part of this process several sites were visited both alongside river corridors and forests. The river corridor visits were conducted by Andrew Newman, Peter Manson, Mike Adye and Fenton Wilson.

Andrew Newman and Brett Gilmore met with the members of the Hawke's Bay Forestry Group (HBFG) and flew over the plantation forests to the immediate south of the catchment (Waikare/Mohaka), and over forests throughout the Wairoa catchment.

Residents have also provided information as to the origin and composition of woody debris.

Observations from the trips are as follows:

River corridors and their condition post Gabrielle

As the major tributaries i.e., Waiau and Wairoa exit the foothills, and traverse the floodplain, the prevalence of very large poplars on and adjacent to the riverbanks is significant.

Figures 8. & 9. Poplars Waikaretaheke Waiau Confluence

Figures 10. & 11. Wairoa River post Gabrielle- significant bank modification

Figures 12., 13. & 14. Poplar debris adjacent to Wairoa near rail bridge and Marumaru and in the Waikaretaheke

Residents have noted that the larger material creating the debris dam on the rail bridge upstream of the township comprised a significant volume of large poplars in some case standing upright against the bridge. Further comment was made that upright poplars within the Wairoa mainstem upstream of the rail bridge toppled powerlines crossing the river. This position is anecdotally similar to that experienced in Cyclone Bola.

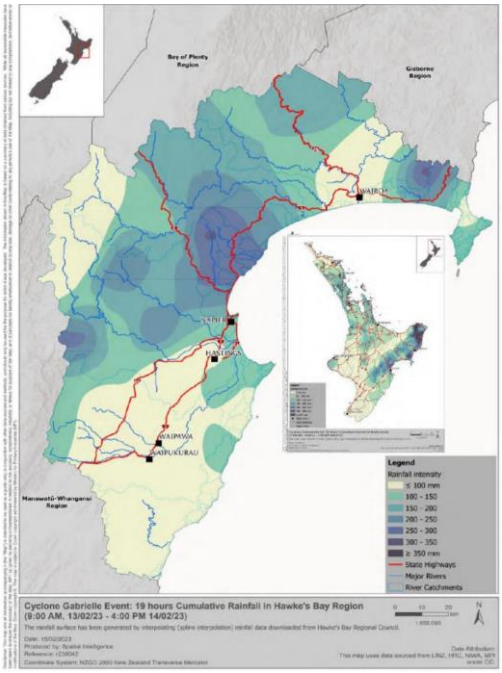
Forestry Debris

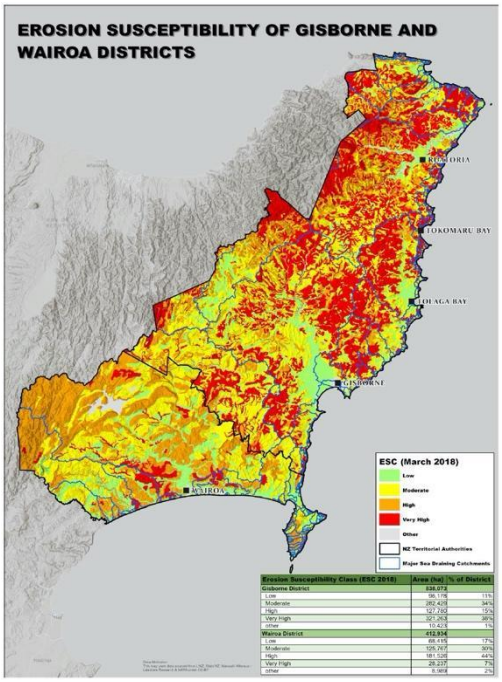
Plantation Forest Condition

Woody debris deposited along waterways, on farms, and on beaches have become a major public issue with much, if not all, the ire targeted at the Forest Industry.

In our discussions with the Hawke's Bay Forestry Group the views were:

'Cyclone Gabrielle's effect on forests within the Wairoa Catchment was minimal compared to elsewhere e.g., Waikare on the Southern Boundary of Wairoa District. There the rainfall intensity resulted in significant whole tree loss due to 'mid-slope' failure.' Figure 15 depicting rainfall intensity through Gabrielle below helps illustrate why this view is valid. Of significance however is that rainfall intensity in the Mangapoike sub-catchment of the Wairoa is like that experienced in the Waikare. The Mangapoike catchment whilst part of the Wairoa extends beyond the Wairoa District Boundary into Gisborne District and its likely that some of the woody debris entering the Wairoa mainstem originated from forests and farmland at the head of this catchment.





Figures 15. & 16. Rainfall intensity Gabrielle, Erosion Susceptibility Gisborne & Wairoa

Also of note is that the northern boundary of the Wairoa/Hangaroa catchment contains the bulk of the land in the catchment that is classified very high risk for erosion susceptibility.

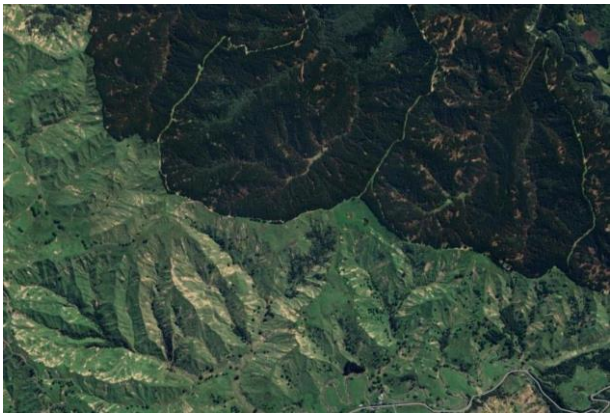


Figure 17. 'Mid slope failure Waikare Forest

Figure 18. Google Earth image of storm damaged forest & farmland between Mangapoike, Tiniroto roads

The Helicopter flight largely confirmed the Helicopter flight largely confirmed these observations as follows:

Damage in the Waikare Forest is significant and in particular involves 'mid-slope failure' and the loss of 10–12-year-old trees in their entirety.

The HBFG view was that Cyclone Hale rain and wind affected Wairoa forests more than Cyclone Gabrielle.

Based on the flyover we agree that windthrow from Cyclone Hale is evident in Wairoa Catchment based forests, but the debris remains within the forests (see figure 19 below).

Otherwise, the Wairoa Catchment base forests are largely intact and harvest practice appeared sound within the main forests. We did, however, sight a recently harvested small block where slash had been poorly managed outside of the Wairoa Catchment (attachment 7).

Figure 19. Windthrow - Forest near Ruakituri

Figure 20. Intact Forest/Farmland near Frasertown

Post Cyclone Gabrielle both HBRC and the HBFG conducted woody debris origin and type surveys across Hawke's Bay and within the Wairoa Catchment (see attachment 6 for a more detailed view on the surveys). The results arising from these surveys differed in some locations. The HBRC survey conducted by Eco Solutions, early March, assessed approximately 90% of the debris at the Wairoa River mouth as being pine based on a flyover and visual assessment. By contrast the HBFG survey conducted by Interpine on March 24, 2023, which involved on the ground surveying found the composition to be 29% Pine/Conifer (incl. 2% slash), 36% Poplar/Willow, and 29% Native. A relatively high proportion of the material was considered aged. This would be consistent with the mobilisation of wood debris already within the rivers ahead of Gabrielle. See attachment 6 for commentary on the survey methods.

Insight

Woody debris has been a recurring issue in all documented storm events over the past century, as has bridge failures.

The composition, over time, within the Wairoa catchment has shifted from native/poplar/willow to poplar/willow/plantation pines/native.

Plantation forest woody debris, whilst a key component, is only part of the woody debris issue and arguably not the major infrastructure risk due to the comparative size when compared with mature poplar trees.

The Bridge Infrastructure affected by debris dams has, except for the Te Reinga Bridge, held up remarkably well. This may be a combination of excellent engineering and, in some instances such as the Kotare Bridge, be reflective of the type of debris that banked up.

Our view is that the Interpine Survey better reflects the woody debris composition that flowed through the Wairoa catchment than that undertaken by Eco Solutions. This is based on the survey method applied by Interpine, the evidence we have found in the landscape, and on local comment re the woody debris flowing through the river during Cyclone Gabrielle.

Pine/conifer based woody debris mobilised by Gabrielle and affecting Wairoa infrastructure (Kotare Bridge/Rail Bridge and the Wairoa River mouth) is likely to have originated in the Mangapoike Catchment. This suggests that rainfall intensities at extreme levels (i.e., 500 millimetres + over 12-18 hours) will damage forest structure with or without recent or current harvesting. Further, research demonstrates that where a weather event is severe enough or part of a sustained weather pattern, no land cover on higher landslide risk slopes prevents slope failure. Sites prone to shallow-rapid landslides remain subject to these landslides, regardless of land use because the landslides' causes are inherent in the landform.

This comment from the authors of the Interpine Woody Debris survey regarding the origins of that debris throughout Hawke's Bay is insightful:

'Almost half, or 48% of the LWD volume measured originated from pine plantation forests, and 38& of the volume was from flood protection willow/poplars. In total, at least 86% of the LWD volume measured originates from unstable, erosion-prone landscapes that vegetation was planted to protect.

Most of the time, outside of significant events, this is achieved succesfully by these plantings. Therefore, the risk of woody debris from forested catchments is inherent in the risk of significant weather events impacting these fragile landscapes. Solutions to mitigate these risks to the recieving environment should be well thought out and alow for the sustainable use of land in an environmental, economic, and social sense in perpetuity.'

Insight

Plantation forests elsewhere in the catchment are largely intact, except for wind throw attributed to Cyclone Hale but even then, the debris remains within the forests.

There is clear evidence of woody debris, likely pine dominant, creating infrastructure damage – Kotare Bridge.

With regards to flow diversion resulting from woody debris dams at the rail bridge – it is likely that this created some backflow into farmland just above the bridge. It also may have reduced flow velocity downstream of the bridge. However, the blockage is highly unlikely to have been a major factor in diverting flows into the racecourse and into North Clyde. Note this issue is dealt with in more depth in Section 6.

Many of the radiata plantation forests established on very highly erodible land in both Wairoa and Gisborne Districts were done so with Government assistance post Bola. Whilst these forests are likely to have reduced silt loss through the last 30 years there is a question as to what is the bigger issue: Loss of silt over an extended period, and/or the impact of woody debris migrating outside of the forest in a storm event? (Attachment 8 – Gisborne District example).

Issue 3 | Silt, Silt Loads and Origin

Unlike Hawke's Bay Catchments further south, the predominant underlying geology of the Wairoa Catchment is siltstone/mudstone and sandstone. There is some limited greywacke located in the far southwest of the catchment and minor deposits of greywacke gravel can be found both in the Wairoa Mainstem and the flood plain. The flood plain is comprised of river and marine layers of silt. A frequent local question is to what degree is a high silt load in the Wairoa River, through the flood plain, an exacerbator of floods due to maintaining a high riverbed and could it be dredged?

It's worth noting that for over 20 kilometres from the sea the Wairoa mainstem continues to be tidal. This means that the natural level of the riverbed is influenced by the bed level at sea level. The long running view of river engineers has been that dredging the riverbed will be an expensive and somewhat 'fruitless' exercise and the bed level will rapidly reset to invert levels influenced by the seabed level, after dredging. A local example of this experience has been lower Clive River dredging.

All Wairoa rivers carry high loads of silt, especially in flood events, even those with significant forested areas due to the catchment geography.

With respect to Cyclone Gabrielle specifically, silt was deposited in flooded areas of North Clyde. In regards its origin, it is highly likely that much of it has been mobilised from the banks of the

Hangaroa, Wairoa and Mangapoike rivers with additional silt having originated from slip failure in the adjacent hill country, from both land that is farmed and has been afforested. Figures 10 and 11 on the Wairoa River show riverbanks that have been scoured of both silt and trees, whereas figures 8 and 9 on the Waiau show intact poplars and silt aggregation around the polars. Figure 18 shows slip damage on both Farm and Forestland.

Insights

The Wairoa River is a siltstone predominant catchment, and any storm event will carry and deposit significant volumes of silt. In the case of Cyclone Gabrielle, the bed level is not a driver or exacerbator of flood levels.

With regards to silt deposition in North Clyde from Cyclone Gabrielle, the origin will be overwhelmingly northern Catchment driven (Hangaroa, Mangapoike, Wairoa) with significant volumes originating along the river corridors and banks, accumulated from past flood events.

Of note is that given the current condition of the northern rivers, the risk of excess silt and tree removal from the banks is now likely significantly diminished in the short term due to the amount removed due to Cyclone Gabrielle.

Issue 4 | Condition of the Wairoa Bar and flood risk due to blockages

The Wairoa River mouth is the main frequently occurring flood risk issue for the lower Wairoa Township, surrounding farms and businesses. This has been the case since Human Settlement. The mouth is either blocked and/or located south or north of an ideal position for most of the time. Even small floods and/or freshes in the main Wairoa River channel build up against the bar and backflow into low lying areas.

The mouth has been manually opened continuously since early European settlement. The methods of manual bar opening have clearly evolved over that time from human to mechanical and progressively between 1997-2000 physical infrastructure options for bar management were investigated but eventually discounted due to complexity, cost, and uncertainty as to efficacy.

Fortunately, in the case of Cyclone Gabrielle the bar was open in an optimal position, as was the case during Cyclone Bola. There is an argument that during a major flood event, such as Gabrielle, there will be sufficient head or pressure to blow open an exit to the sea at the mouth even if the bar is in a sub-optimal or semi closed position. However, if this is the case there will remain a question of timing. This is dependent on whether there is a build-up of flood waters ahead of the bar blowing open.

HBRC is the governing authority with accountability for management of the river mouth. During the tenure of the Catchment Board a river engineer was based in Wairoa with accountability for river mouth management. At the formation of the Regional Council, engineering operations were centralised out of Napier and the responsibility for mouth opening decisions transferred to other Wairoa based HBRC staff. These staff worked closely with one local contractor. Through that time the bar has been successfully manually opened approximately 20 times[7] ahead of significant storm events. During that period there were, according to the personnel involved, no flooding issues other than for the yacht club, located in the lower berm section of the river.

The view of all the personnel involved through this period is that there is a significant degree of onsite judgement, coupled with experience, required for a successful and timely manual bar opening. These involve a balance of timing, river flow head and sea conditions.

In recent years, the practice has changed whereby HBRC makes the bar opening decision from Napier using the same contractor. There is a Wairoa Community view that the bar opening process is riskier than that previously in place. In large part this perspective has formed because of the view that local decision making, institutional memory, and experience has diminished. An example of this is the flooding of a local business, the Limery, and surrounding land near the river mouth on November 26th, 2023.

Insights

The Wairoa River mouth is, and will remain, the most frequently occurring flood risk for the lower section of the Wairoa River, including the Wairoa Township. Whilst a major scale event such as Cyclone Gabrielle will eventually blow an exit through the mouth in the absence of human intervention and in the absence of an optimal channel, there is significant benefit in having local expertise and contractors that are able to monitor and respond to onsite conditions prior to and during any significant flood event.

In the absence of more costly infrastructure solutions for the mouth, recent history suggests there is a solution i.e., the use of expert local based staff and contractors being given sufficient discretion to make timely decisions on mouth opening. This approach requires an institutional continuity of approach.

[7] Key person recollection

Issue 5 | Lake Waikaremoana Hydroelectric Scheme

Lake level and flow management and its contribution or otherwise to flood flows immediately downstream and through North Clyde

Questions have and continue to be asked as to whether flood flow releases from the Waikaremoana Power Scheme were a significant factor contributing to flooding of North Clyde during Cyclone Gabrielle; despite the release of a joint public statement from Genesis and HBRC reported shortly after Gabrielle. The statement, made in strong terms, was that flows originating from the scheme through Gabrielle were in the order of 40 cumecs and in line with consent conditions. That the lake level was dropped ahead of Gabrielle, water was then stored in the lake during Gabrielle, and that the releases contributed less than 1% of the comparative flow at the rail bridge.

Genesis has since commissioned an independent hydrological audit on its flow management of the scheme from November 2022 through to Cyclone Gabrielle[8].

This audit lays out clearly the scheme management pre-Gabrielle and through Gabrielle validating the Genesis-HBRC view specifically in relation to flooding within the North Clyde area of Wairoa. When queried HBRC did note some flow statistics used in this report, notably those at the Rail Bridge were preliminary. Even so, any adjustments to the flow numbers will be extremely unlikely to materially change the scheme flow contribution ratio through Gabrielle.

Other data and observations also support this. Critically the audit notes the spillway at the lake intake has never been used and was not used in Gabrielle. The current state of the spillway, covered in sedimentation and grasses and weeds that appear to have been there for a long time supports this. Water released therefore flowed through the intake pipes at Onepoto Bay and through the siphon diversion system (via pipes which run under the spillway structure)[9]. This means here is hard infrastructure limit on the overall scale of flow releases that Genesis has full control over.

There is unmistakable evidence that the major, more damaging, flood flows originated in the Northern part of the Wairoa catchment i.e., the incidence of severe flood scouring on the Wairoa in comparison with the Waiau. Weather station, and flow data from the Northern end of the Catchment (Hangaroa/Wairoa/Mangapoike) suggests flows 2.5 times the scale of those in the Waiau.

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

[9] The Waikaremoana scheme has a siphon system for diverting water past the power stations.

Having said this there was flooding of amenity assets around Lake Waikaremoana before, during and after Gabrielle, andlocalised flooding of farmland downstream of the scheme on the Waikaretaheke during Gabrielle and from high rainfall events shortly thereafter at levels not previously experienced according to local comment (Attachment 3). The peak flows observed at the Piripaua Bridge (Total Power Scheme Outflow) were high but not exceptional, occurring 8 times in the last 20 years. Whereas the flow record only 4 kms downstream from Piripaua at the Waikaretaheke at Terapatiki flow station shows the highest flows since records began at the site reaching 170 m3/s. This flow data points to extremely high intensity rainfall in a very localised area.

Based on a site visit with Genesis staff and a subsequent set of question and answers (see Attachment 3) the following observations are made.

Lake Waikaremoana flooding – the continual high inflows over an extended period have made lake level management quite challenging and infrastructure capacity limitations coupled with consent peak flow restrictions means that it takes some time to reduce high lake levels. The 12 months preceding Gabrielle saw the highest ever annual inflow sequence which is also double the long-term average. When large rainfall events hit Lake Waikaremoana the lake level responds because these inflows are far beyond the outflow capacity of the scheme.

Flooding downstream of the scheme during Gabrielle – the hydrological records independently audited for Genesis[10] show that the inflows from streams, not connected to the scheme, into the Waikaretaheke River were significant contributors. See figures 21 and 22 below[11].

[10] SLR Waikaremoana Power Scheme Hydrological Audit, August 2023

[11] Source -note from Genesis, March 22, 2024

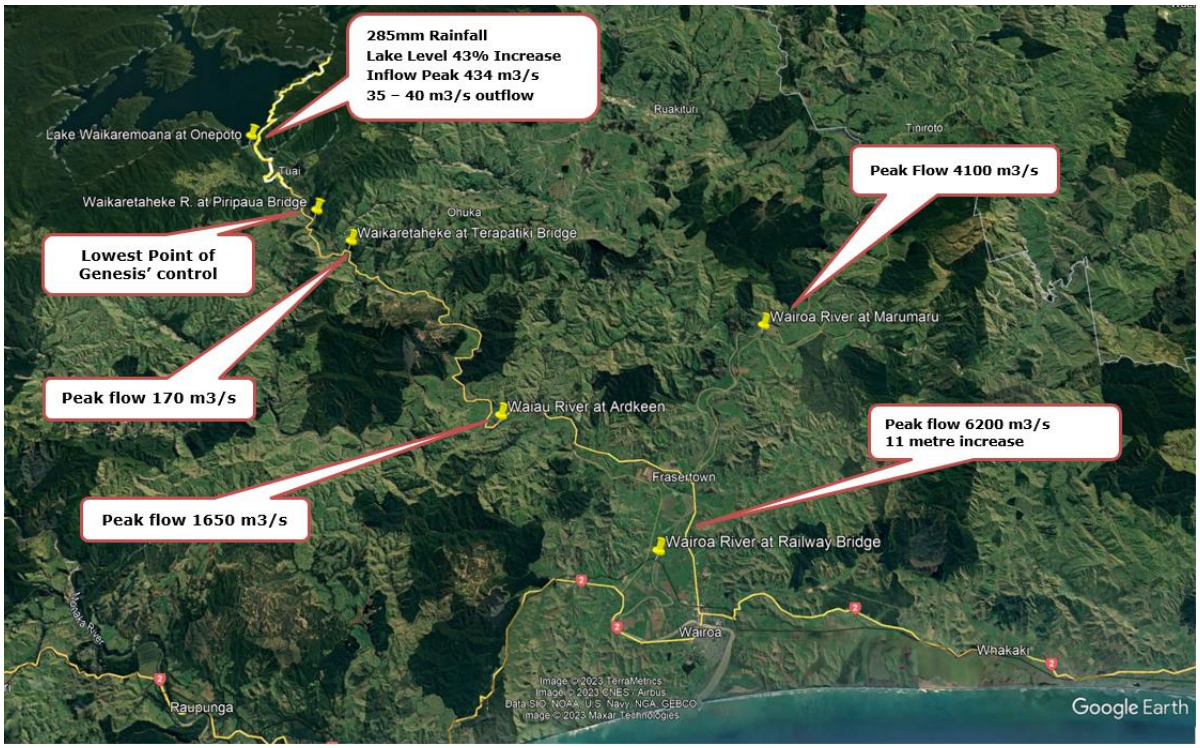


Figure 21. Stream flows in, adjacent and downstream of the Waikaremoana Hydroelectric Scheme during Cyclone Gabrielle

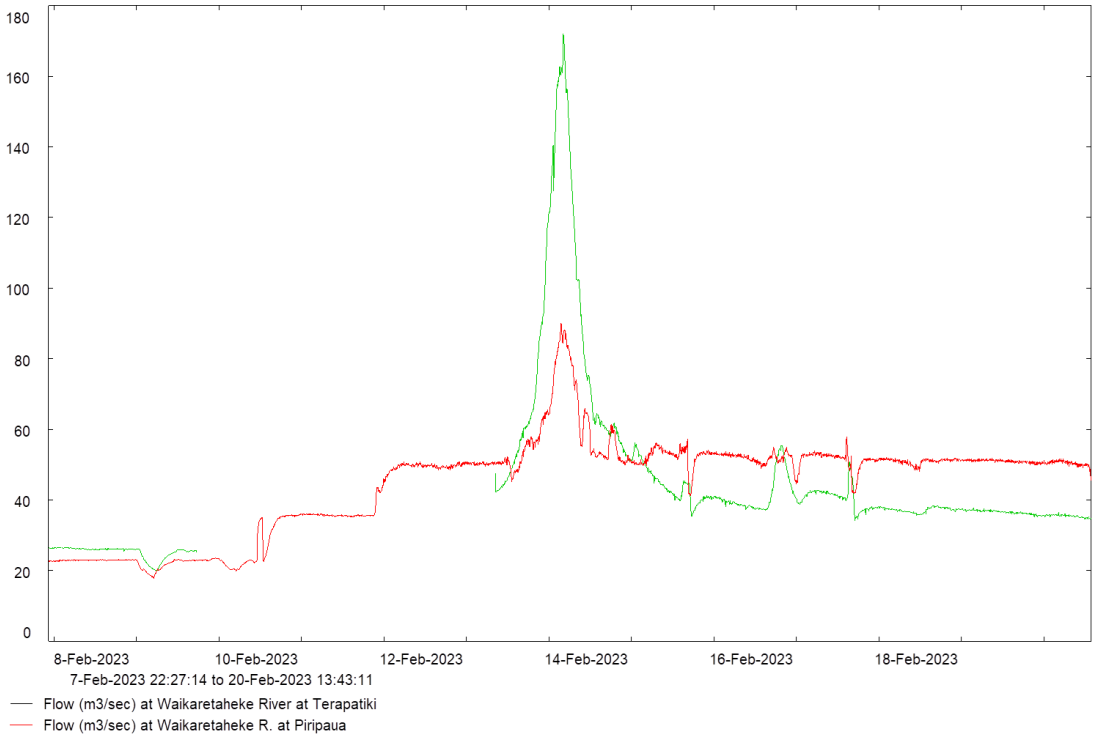


Figure 22. Hydrograph Waikaretaheke - Cyclone Gabrielle

Insights

The question, given this evidence, is why does the conjecture about the Power schemes contribution to damaging flood flows persist?

It is possible that local attitudes towards the scheme and perceptions as to its contribution to serious issues, such as North Clyde Flooding, are associated with localised issues including;

1. *The incidence flooding flows into and around the lake and the Waikaretaheke catchment over an extended period and,*
2. *Localised rainfall events of very high intensity, that are difficult to forecast, difficult to manage quickly and have created significant stress for all those who live and operate within this part of the Wairoa Catchment.*

Consistent with other comments through this review the coupling of the antecedent soil moisture conditions with extreme storm events might be a trigger for increased communication within the local community ahead of time as to potential risks, possible consequences and the proposed management strategy.

Section 6 | Flooding of North Clyde and other areas in and around Wairoa

The issue (s)

Cyclone Gabrielles flooding of the North Clyde area of the Wairoa Township is the largest scale issue associated with this event. Flood waters drove the displacement of people from their homes and businesses. Taonga, including iconic marae such as Takitimu and Tawhiti a Maru Marae were placed at risk. Property damage was extensive due to the depth of flows and the deposition of significant volumes of silt. Other people and property were also severely affected in the Wairoa Campground, Awamate area, around and just above the rail bridge, and along the Wairoa River downstream of Marumaru. These effects are still being felt today with people either displaced and/or living in temporary accommodation. Uncertain as to when, and under what conditions, permanent reoccupation of their homes will be allowed. Why did North Clyde Flood?

Issue 1 | Scale

There is strong repeated evidence of significant flooding of North Clyde since the establishment of the Wairoa Township. Documented events include 1911, 1948, 1988 and now 2023.

Figure 23. North Clyde and Wairoa River 1948

Figure 24. North Clyde - Cyclone Gabrielle

The 1948 storm was analysed in detail as part of HBRCs development of flood mitigation options for Wairoa through the late 1990's to early 2000's. The analysis undertaken by Gary Clode[12] in 1994 continues to provide an excellent baseline for understanding 'flood behaviour' and has been referenced in the work currently being undertaken by WSP on flood risk mitigation options for Wairoa. Because of this analysis, referenced in subsequent HBRC reports thereafter, the 1948 event scale with a peak flow rate of 8,200 cumecs was identified as a 1 in 100-year event by the Ministry of Works and Developments 1987 report titled SH38 Waiau River Flooding. Noting however that there was an allowance for a wide margin of error in the flow estimate of plus/minus 35%. The most up to date preliminary estimates for a 1 in 100-year event now suggest a lower peak flow number of 6,700 cumecs in a 1 in 100-year event based on 'current climate conditions' versus the estimated 8,200 cumecs derived in 1994[13]. Post 1994, a flood model incorporating elements of this work and updated Lidar data was developed and reported in 2006 showing the extent of flood water forecast from a 1 in 100-year event (see figure 23).

[12] HBRC Design Engineer

[13] Correspondence between HBRC and Andrew Newman

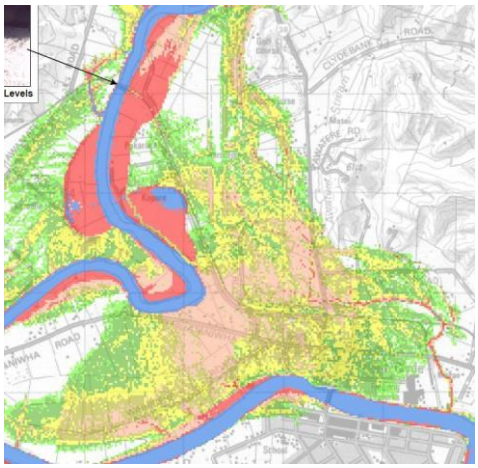


Figure 25. 1 in 100-year flood model HBRC 2006

This work clearly identifies the risk of flooding in North Clyde and along the mainstem margins including the Wairoa Campground location.

Numbers provided by HBRC and quoted in the independent Waikaremoana Power Scheme Hydrological Audit regarding the flow scale at the Wairoa rail bridge at the 'Gabrielle Peak' was 7900 cumecs[14]. However, in correspondence with Andrew Newman on March 6, 2024, HBRC notes the Gabrielle preliminary peak flow number has been revised to 6,200 cumecs and that the 1 in 100-year exceedance number is identified as 6,700 cumecs based on 'current' climatic conditions.

Estimated Gabrielle peak flows are inside the margin of error identified for the 1948 flood peak flows. This really reinforces that flow estimation, particularly of flood events over 75 years ago, is not an exact science. Despite some ambiguity in the flow statistics, estimated for historical events and better measured for recent events it is reasonable to note that it's primarily the scale of the event which caused the North Clyde flooding.

Other key points

NIWA's 'Extreme value analysis of the flood flows that occurred during Gabrielle noted the following values for KEY Wairoa tributaries.

Tributary	*Flow estimate cumecs*	*Pre- Gabrielle ARI*	*Post- Gabrielle ARI*	*Flow record*
Wairoa Marumaru	4,100*	250	120	1980-2023
Hangaroa Doneraille Park	2070	420	220	1974-2023
Ruakituri at Tauwharetoi	998	50	40	2013-2023
Waiau at Ardkeen	1656	50	40	1988-2023

[14] In a question to HBRC these have been qualified as being preliminary. Of further note is these numbers have not been provided to WDC as far as I am aware.

*WSP flood model adjusted the HBRC gauged flow data of 4,912 cumecs – see attachment 4 for an explanation of this.

HBRC in correspondence has noted that the current estimate for a 1 in 100-year, event is 6,700 cumecs for current versus the 6,200 cumecs estimate for Gabrielles size or approximately a 1 in 90-year (ARI) event for the catchment as a whole.

Issue 2 | Flood flow diversion at the Rail Bridge

As noted in Issue 5.2 significant woody debris banked up against the rail bridge. Local recollections note that there was a backup on the upstream side of the bridge with the water level (anecdotally) 1-1.5 m lower on the downstream side at or near peak flow approximately 8:00am –11:00am. The question that arises is; was this blockage of a sufficient scale to divert the flow out of the main stem, to the extent it caused flooding in North Clyde, that would have not otherwise have occurred?

Effect of the Rail Bridge Debris Dam

The Rail Bridge debris dam effect at most was likely to have been slowing flow velocity downstream of the rail bridge and into North Clyde and some back up potentially raising water levels locally in adjacent farmland just upstream.

More accurate than this is the response provided by the Flood Flow Modelling engineer of HBRC.

Review Questions

Neighbours adjacent to the Wairoa Railbridge report a significant woody debris build up against, on and adjacent to the bridge (ie. Embankment). Further commentary suggests a flow differential of (anecdotally) 1-2 metres in elevation between upside and downside of the bridge at or near peak flow. As per the Wairoa Community Stakeholder group process assessing flow mitigation options – I understand an allowance equating to 10% of the total flow is modelled as backflow – affecting farm properties upstream with 90% of flow continuing dow n the mainstem and through the showgrounds – North Clyde area. This leads to 2 questions:

1. Without the bridge would the flows have remained within the mainstem? Or would North Clyde have flooded regardless? - Lidar levels and flow records will/have verified this.
2. Pretty speculative I appreciate but is there any view as to the impact of the rail bridge blockage on flow velocity?

HBRC Flood Flow Modelling engineer of HBRC comment;

As demonstrated below in figure 26, the effect of blockage at the railway bridge would only have an effect of reducing the overflow into North Clyde. Imagine if the rail bridge could block a huge portion of flow and maintain the water in the channel (i.e., no out of channel flow). This would

result in water arriving at the overflow into North Clyde at a slower rate and would result in lesser flooding. As a corollary, if there was no blockage at the rail bridge, the water would arrive at the North Clyde overflow earlier, and with a higher discharge, causing worse flooding.

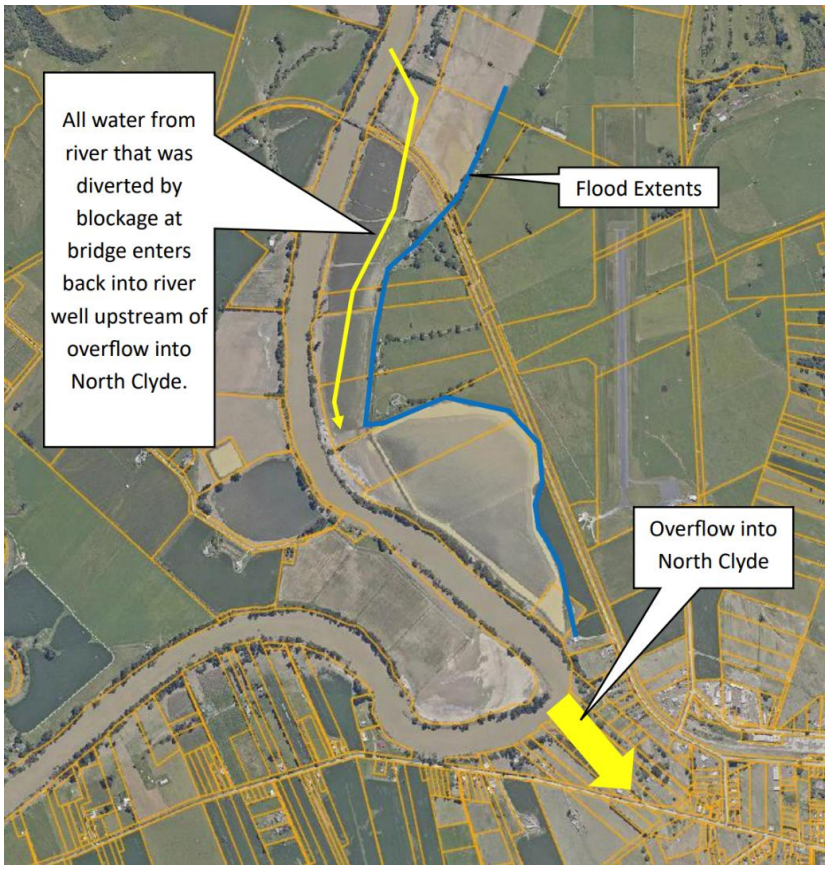


Figure 26.

An observation of residents was that whilst the Wairoa River overflowed into North Clyde, the water exiting North Clyde dropped back into a lower river channel – with the question being why the differential in levels? This issue is best described by the noting that the North Clyde area is part of an old natural flood plain of the river. Once flood flow levels reach an extreme level as was the case in the 1948 flood event and Cyclone Gabrielle a considerable proportion of the flow will spill into that part of the old flood plain and in so doing will part disperse or reduce the flow down the normal river channel (figure 23). The flood mitigation options currently being explored by WSP, and the Community Stakeholder group reflect this dynamic. Clarification of the level differentials between the Rail Bridge, North Clyde, the Town Bridge and downstream of the Town Bridge could be sought from HBRC/WSP to further clarify this point.

Issue 3 | Warning or lack thereof

Fortunately, whilst there was no direct loss of life many residents and businesses within areas including Marumaru, the Wairoa Campground, Awamate and North Clyde were distressed by the lack of warning and the speed of arrival of the flood waters.

A few factors are at play in this issue as follows.

1. The intensity of rainfall from Gabrielle especially in the Mangapoike Catchment over a short duration (possibly 25% of the peak flood flow recorded at Maramaru may have originated out of this catchment).
2. The short steep catchments from which the flood flows emerged.
3. Antecedent ground conditions in the catchment
4. The absence of intense rainfall within and adjacent to the Wairoa Flood plain where most people were affected.
5. State of the River mouth?
6. The critical failure of flood warning communications systems at approximately 1:00am on February 14.
7. Arguably a lack of community awareness of risk; community memory of flood risk being associated with Bola, not the 1948 floods.

Issue 4 | Surprise as to the areas flooded

Surprise has also been expressed by some that the North Clyde flooding was unexpected, and why was the flooding from the Gabrielle event different from that experienced during Bola. One feature of Gabrielle was that the Wairoa Campground on the upstream side of the main town bridge started flooding at 3am and people self-evacuated between then and 6:00am[15], significantly earlier than North Clyde.

Flooding of North Clyde occurred in 1948, 75 plus years prior to Gabrielle. Some residents still remember that event, but they are very few.

Regarding localised flooding, an example being the Wairoa Campground, the HBRC flood model does identify this area as being at risk. Of note the modelling suggested a 1 in 20-year event could create localised flooding within this location, this may explain the earlier arrival of flood water than was the case for North Clyde.

[15] Bill Dickin – Wairoa Campground manager

Whilst HBRC undertook significant work on analysing flood risk to North Clyde and Wairoa more broadly two/three decades ago, it is hard to say how much of that resonated with the community and its successive generations of leadership.

Insights

Cyclone Gabrielle was an exceptionally large and extreme event, especially across the Northern Catchments Hangaroa/Mangapoike and in the Wairoa mainstem.

Substantial differences between Bola and Gabrielle, other than scale, include the amount of rainfall preceding Gabrielle, leading to a very wet landscape and antecedent conditions, and the short sharp intensity of rainfall during Gabrielle versus the reported dry year preceding Bola and the duration of the rainfall over 3-4 days.

The most recent flow statistics for Gabrielle are a substantial improvement in those obtained for Bola and the margin in scale is highly likely higher than the numbers for Bola (5,000 cumecs peak flow at the rail bridge during Bola versus peak flow at the rail bridge during Gabrielle 6,200 cumecs).

Whilst the rail bridge woody debris dam did likely reduce flow velocity through the mainstem and into North Clyde it is highly unlikely to have been a causal factor in diverting flows into North Clyde and areas adjacent or exacerbating what would have occurred anyway.

As noted previously it was the northern sub-catchments of Wairoa system that provided the bulk of the flood water, along with wet antecedent conditions in Cyclone Gabrielle. This is reinforcing the point that flow releases through the Waikaremoana hydroelectric scheme which transition through the Waikareteheke to the Waiau rivers were not a material contributor.

An implicit, if not explicit, contract between HBRC and the Wairoa Community in the absence of 'hard infrastructure' for flood protection was to provide early warning of a flood event to local civil defence. In this regard the failure of communications at the critical time (for whatever reason) was extremely unfortunate. Particularly as the core weather station and flow monitoring infrastructure continued to operate.

In years where there are extremely high soil moisture levels preceding potential storm events and an elevated risk of sub-tropical storm events there is a need for a heightened community awareness of flood risk potential.

Finally, and most importantly, it would appear the North Clyde area of Wairoa is exposed to flooding from events that are less than 1 in 100 AEP probability and that with climate change this risk will increase.

Section 7 | What are the lessons from Gabrielle?

Issue	Risk	Response	Accountability
Catchment soil moisture saturation ahead of storm events	Significantly heightens flood risk of North Clyde and surrounds and shortens warning times	Should be a key factor in Civil Defence planning – if not already so.	Civil Defence HBRC data Infrastructure operators
Woody debris	Is a risk to infrastructure primarily	Riverbank tree management – extension of HBRC rivers schemes – needs analysis on what if anything can be done vis poplars – Southern catchment focus predominantly. Plantation forestry – prime risk is - planting and harvesting on extreme erodible areas – mainly northern Wairoa Catchment Poor harvest slash management practice – may be higher on small block one off operations. Some commentary on returning extreme risk areas to native – but establishment complexity and time will be major factors – let alone cost.	HBRC rivers schemes Forestry Co's and regulators
Silt Loads	Silt deposition in urban and high value primary production areas	Manage the Northern rivers to maintain their current state. See comments above vis Southern rivers	HBRC
Wairoa River mouth	Frequently occurring risk Wairoa Township and surrounds	In the absence of a viable infrastructure solution – revert to locally based oversight and management of manual bar openings, including pre-emptive and early preparation opportunities.	HBRC (WDC)
Waikaremoana Hydroelectric Scheme	Flooding risk around the lake, and immediately downstream	Proactive Genesis Community comms ahead of issues	Genesis (WDC)

Table 2. Underlying issues and or drivers influencing flood flows

Issue	Risk	Response	Accountability
There no 'silver bullet'	Increasing frequency under Climate Change	Community response via WSP project Retreat – not an option – so in addition to flood channels, embankments – house lifting? i.e., adopt more than one solution	HBRC/WDC/Iwi/ Homeowners/ Businesses
Flood flow modelling & statistics	Modelling and statistics are fundamental to flood infrastructure design – there's a risk given the progressive changes in flood scale understanding that the community sentiment becomes skeptical	The flood modelling and flow statistics need to be communicated to a wide audience by the key HBRC staff qualified to do so – as part of the overall engineering response	HBRC
Flood warning - communications	Lack of warning – lives placed at risk	Ensuring communication systems durability and more than one method is critical.	Civil Defence/Lifelines agencies/HBRC
Influence of the rail bridge	Flow velocity	May be best to leave rail bridge as is but reduce woody debris risk – especially poplars	HBRC Kiwi Rail

Table 3. Flood flows through North Clyde- community and infrastructure adjustment

Attachment 1 | People engaged.

Person	Role	Issue or Area
Craig Little	Mayor of Wairoa	
Denise Eaglesome-Karekare	Deputy Mayor of Wairoa	
Wiki Hauraki	Chair Takitimu Marae	North Clyde flooding
Lace Blake	Whaakirangi Marae	Frasertown
Leona Kararuia	Tapokorau	North Clyde
Brian Wilcox	Huramua Marae	Awamate
Larence Yule	Facilitator of Community Stakeholder Group	Flood Mitigation options
Dave Martin	Farmer	Frasertown
Dave Hayward & Kate Standring	Farmers	Paeroa
Fenton Wilson	Farmer/QRS Director	Frasertown
Andrew & Tracy Powdrell	Farmers	Awamate
Michael & Roz Thomas	Farmers	Adjacent to rail bridge
Jeremy Harker	QRS	Woody debris & bar
Alan Cooper		Wairoa bar
Melissa Kaimoana	Councillor	Wairoa District
Benita Cairns	Councillor	Wairoa District
Hamish Pryde	Pryde Contracting	Wairoa Bar
Blake Chateris	Chateris Helicopters	Overview of Gabrielle Flooding Wairoa Catchment
Rick Clarke	Farmer	Near Rail Bridge
Diane Downey	The Limery	Wairoa River Mouth & Bar
Bill Dickin	Wairoa Campground	Camp Ground flooding
Richard Grimmett	WDC	Woody debris
Michael Hardie	WDC	District Infrastructure
James Powrie	CEO Hawke's Bay Forestry Group	Plantation Forestry
Damon Wise	PanPac	Plantation Forestry
Steve Bell	Forest Managers NZ	Plantation Forestry
Matt Doyle	Forest Managers NZ	Plantation Forestry
Graham Douglas **via James Powrie**	Juken Nissho	Plantation Forestry
Tracey Hickman	Genesis Energy	Waikaremoana Hydroelectric Scheme
Gareth Gray	Genesis Energy	Waikaremoana Hydroelectric Scheme
Chris Mirams	Genesis Energy	Waikaremoana Hydroelectric Scheme
Ross MacDonald	Genesis Energy	Waikaremoana Hydroelectric Scheme

Attachment 2 | References

Letter from Craig Little, Mayor of Wairoa to Hinewai Ormsby, Chairman Hawke's Bay Regional Council, 16 March 2023 - with a list of questions re Cyclone Gabrielle and its causes and effects.

Letters dated 9 & 23 June 2023 from Chair Hinewai Ormsby, Chairman, Hawke's Bay Regional Council responding to Craig Little, Mayor Wairoa District – addressing questions raise in 16 March 2023 letter

Memo 4 September 2023 from Acting Manager Science to CEO Hawke's Bay Regional Council – covering 'Wairoa Rainfall and River Flows in Cyclone Gabrielle'.

Hawke's Bay Regional Council response to request for information from the Government Inquiry into the North Island Severe Weather Events – submitted 19 October 2023

Cyclone Gabrielle – Woody Debris Species Composition Assessment, Ecological Solutions, March 31, 2023 – prepared for Hawke's Bay Regional Council

Cyclone Gabrielle – Post Event Woody Debris Assessment- Hawke's Bay, prepared for the Hawke's Bay Forestry Group, 24 April 2023, Interpine Innovation

Wairoa Floodplain Management – progress report to July 1994, Hawke's Bay Regional Council

Flood Mitigation – Wairoa Urban Area, Hawke's Bay Regional Council, March 1997

Wairoa Flood Protection, Hawke's Bay Regional Council, February 1999

Wairoa Flood Protection, Hawke's Bay Regional Council, January 2000

Waikaremoana Power Scheme, Hydrological Audit, prepared for Genesis Energy Ltd by SLR Consulting NZ Ltd, 28 August 2023

NIWA 'Extreme Value Analysis of ex Tropical Cyclone Gabrielle Flood Flows in the Hawke's Bay Region – letter to HBRC 23 February 2023.

Outrage to Optimism - Ministerial Inquiry into land use associated with the mobilisation of woody debris(including forestry slash) and sediment in the Tairawhiti/Gisborne District and Wairoa District, May 2023

Attachment 3 | Questions of and Responses from Genesis Energy

Genesis Comments

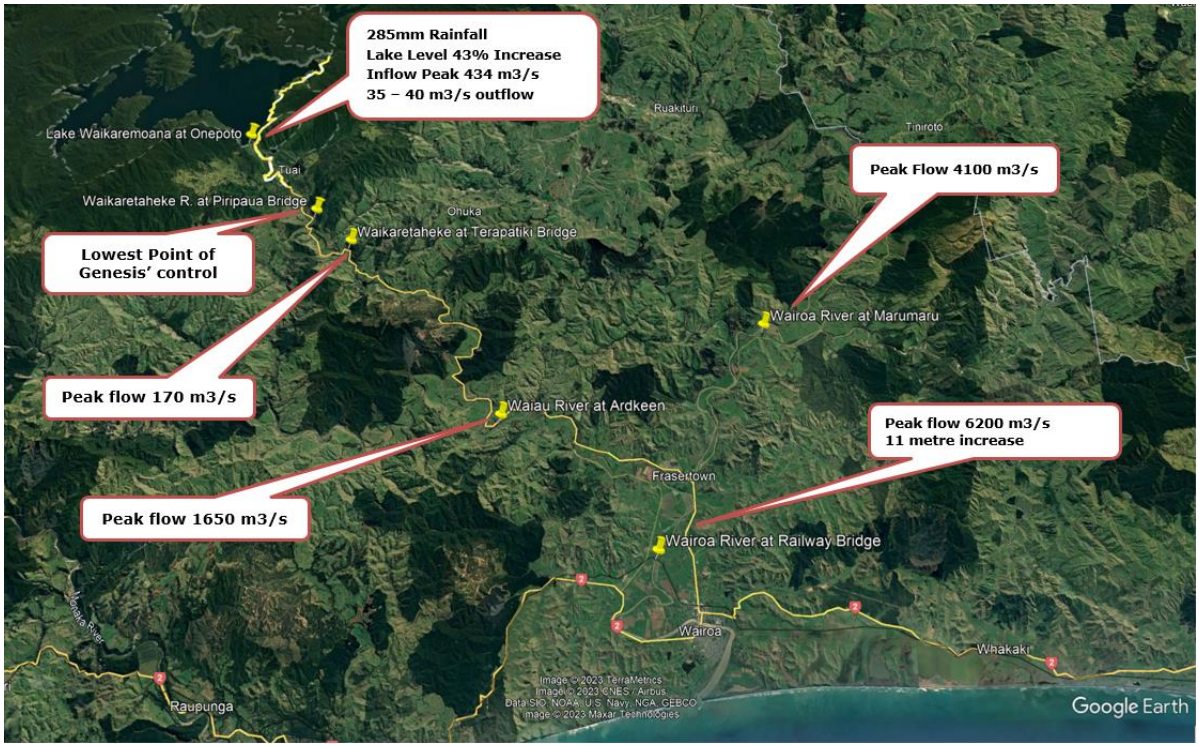
It's important to remember that the level of Lake Waikaremoana was reduced by approximately 5m during construction of the scheme which enables flood flows to be stored and not propagated downstream.

Flooding was driven by a combination of factors. In the leadup to Gabrielle the lake was lowered 6% to mitigate the effect of inflows from the pending cyclone. Subsequent rainfall events after Cyclone Gabrielle further delayed the lowering of the lake level which returned to its consented range in March and has not exceeded it since then.

Also, for added context, Gabrielle was one event over an extended period of extreme rainfall events and inflows to Lake Waikaremoana which saw the highest ever average annual inflow since records began.

Regarding Gabrielle, there was intense localised rainfall beyond the scheme's last point of control, Piripaua Bridge, which contributed significantly to the flows that went to Wairoa. This is highlighted by the maximum controlled flow release from the Lake Waikaremoana 40 cumecs compared to flows below the scheme of approximately 90 cumecs.

This is illustrated well by the graphic below which shows the different points and flows. (I may have shared it with you before but it's worth seeing in relation to the above and gives a good visual of what was flowing and from where)



Review | Question 1

Re localised flooding downstream of the scheme – your perspective is that the flooding is driven by a combination of very intense rainfall in the area just 'upstream' delivering water into tributaries including but not limited to the Mangaone Stream and that this issue rather than the scheme contribution flows being the primary driver of the flooding. To reinforce this your point is that throughout Gabrielle (and the subsequent event?) the maximum flow release from ~~the scheme both through the turbines and diversions~~ Lake Waikaremoana was circa 40 cumecs. Whereas flows at or just below the scheme were circa 90 cumecs.

Genesis Response

Andrew, please note the correction to the above paragraph.

Review Questions | Question 1 Continued

In terms of my work and based on yesterday's discussion I'm keen to get a handle on some relatively basic stats –

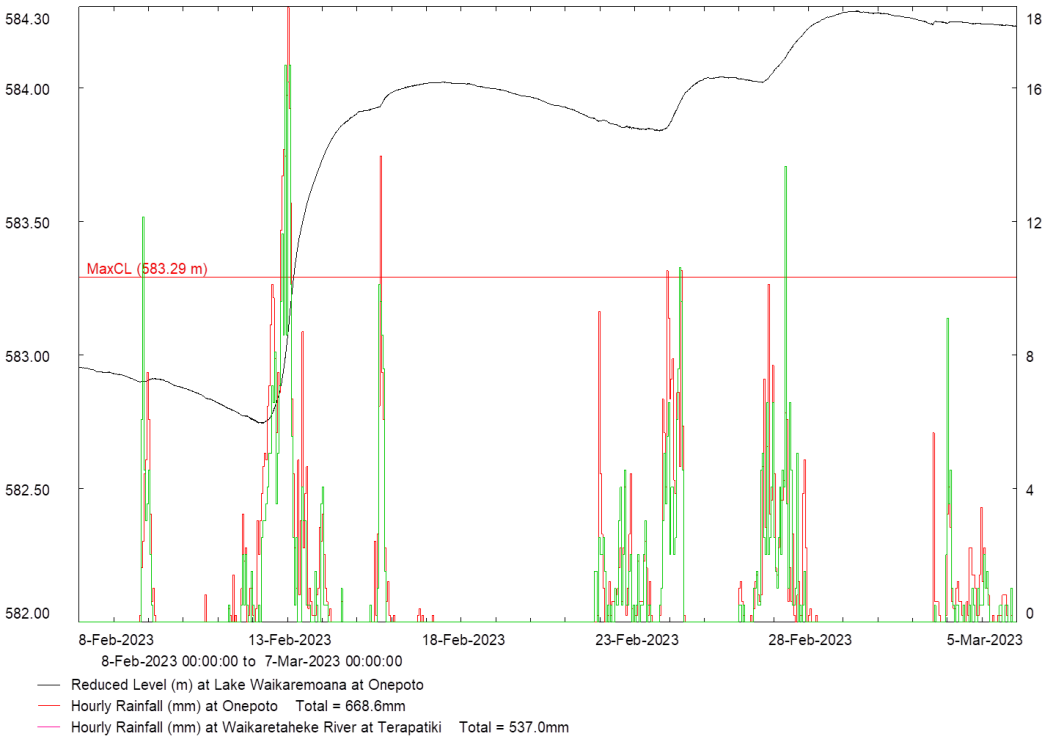
1. the rainfall accumulations at both the "Genesis rain gauge at the primary intake and the HBRC gauge at Terapatiki for both the Gabrielle and subsequent February Flood event.

Genesis response

In the table, Onepoto is the Genesis Energy rainfall data and the HBRC Terapatiki rain gauge is approximately 4km below Piripaua Station, plotted with the Lake Waikaremoana water level response.

Date	Onepoto Rainfall	Terapatiki Rainfall
10-17 Feb	327mm	242mm
22-25 Feb	155mm	123mm
26 Feb – 1 Mar	108mm	102mm
4-6 Mar	46mm	35mm

I have confirmed the spillway invert as 585.51m, this is the small spillway structure that has never been used since the time the scheme has been built.



Review | Question 2

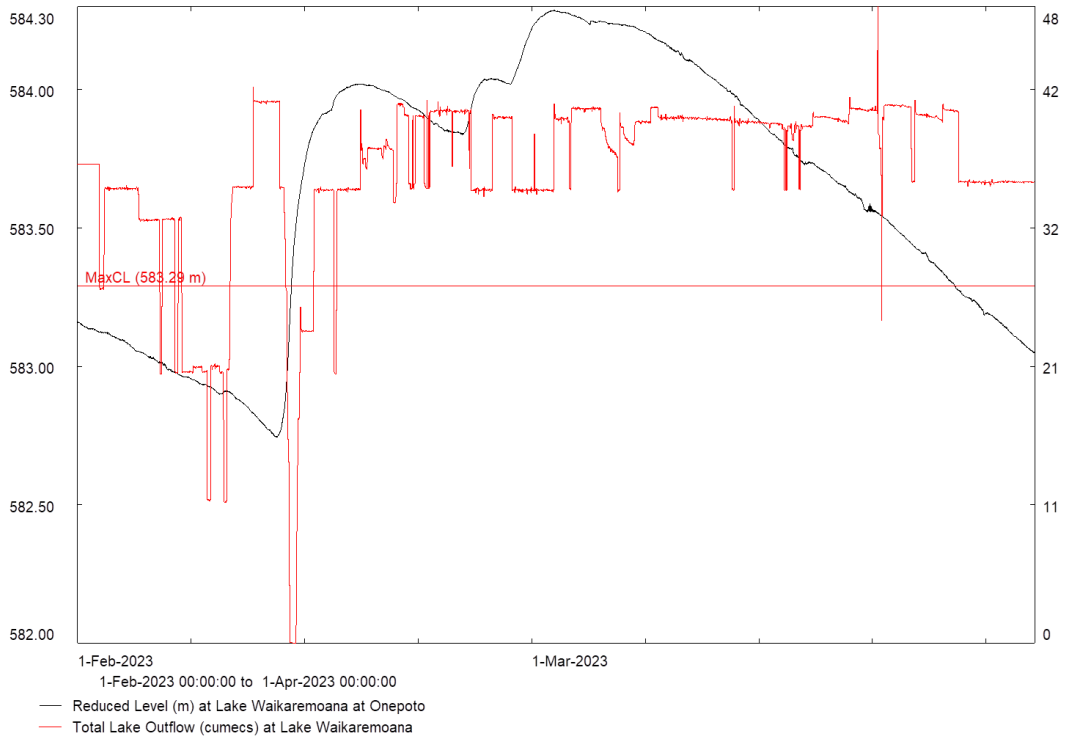
Confirmation of the 40 cumec flow

Genesis Response

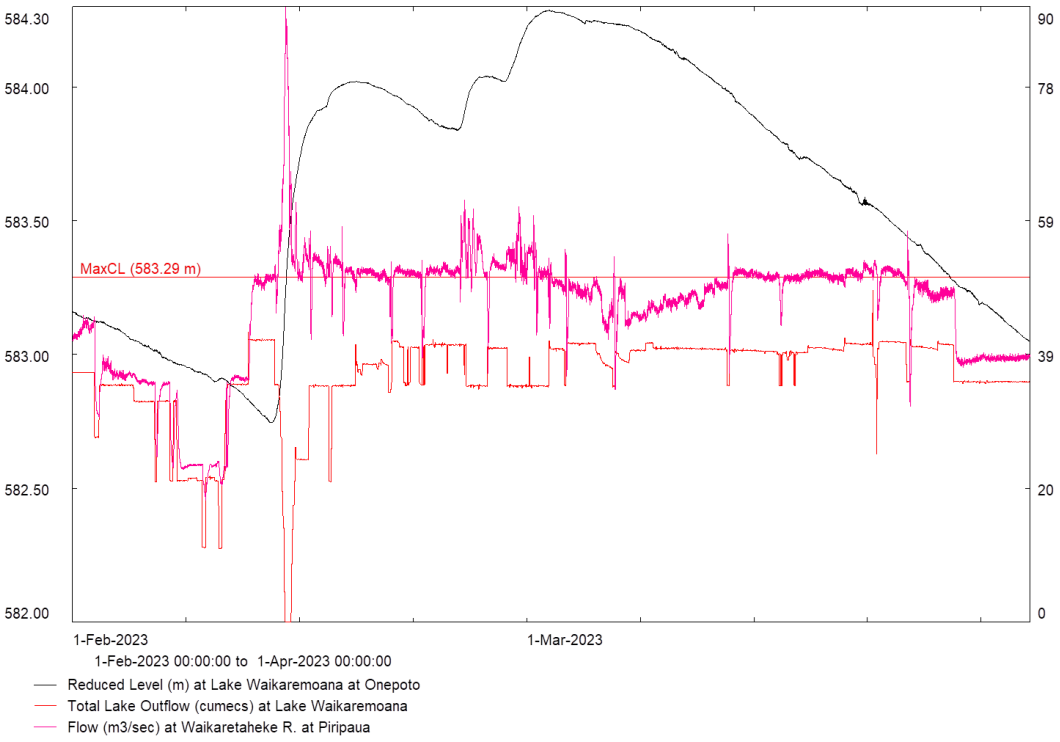
For background, it's important to remember that the average inflow to Lake Waikaremoana was higher in the 12 months to June 2023 than any other 12-month period since records began in 1930, twice the long-term average.

a) The plot below shows the total combined discharge from Lake Waikaremoana, in the lead up to, during and after the high lake level. It shows the 35-40m3/s discharge from Lake Waikaremoana. The only time when this was significantly reduced (14th Feb) was during Cyclone Gabrielle itself when the Kahuitangaroa Stream peaked at 28.7 m3/s and Redcliffe went offline so we managed the high scheme flows during this time to comply with several scheme lake levels and flows. The other 5 m3/s reductions in the trend are when the Kahuitangaroa Stream was discharging high flows from the subsequent rainfall or during times when we had to clean the screens at the Waikaretaheke Diversion, which results in a nett reduction in controlled outflow from Lake Waikaremoana.

For complete clarity, the red trend is the amount of <u>controlled discharge from Lake Waikaremoana</u>. There are natural inflows (Kahuitangaroa and Mangaone and leakage) that enter the catchment within the limits of the WPS which saw flows increase to 90 m3/s on the day of the flooding.



b) The second plot highlights the Piripaua Bridge (scheme total flow including those natural inflows from the Kahuitangaroa Stream, Mangaone Stream and leakage). Remembering all of this was operated while Piripaua Station was completely offline for planned maintenance, so the total scheme flows plus natural flows passed under the bridge.

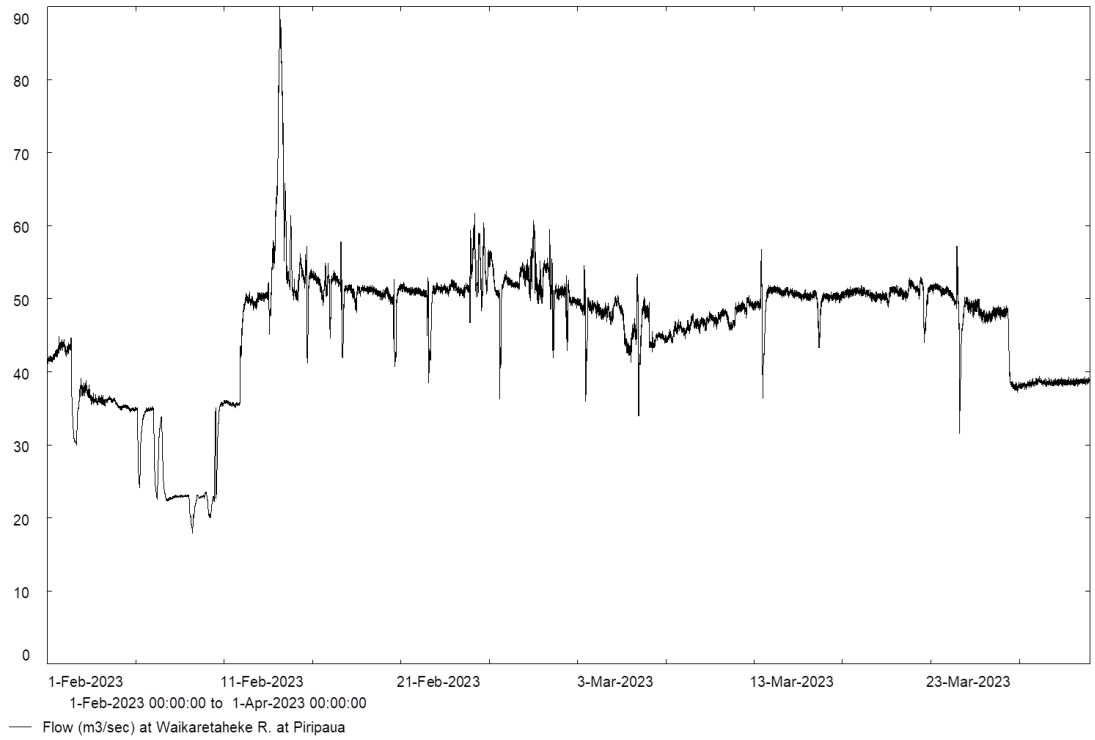


Review | Question 3

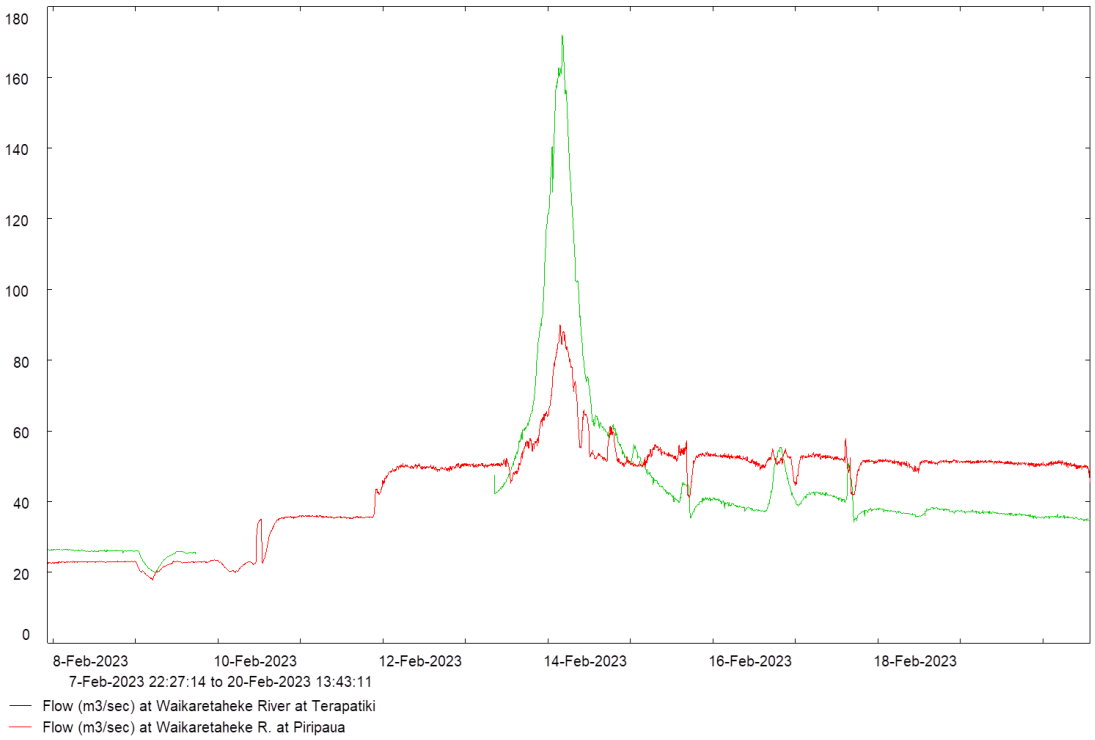
Flows at the gauge point on the Waikaretaheke at or below the exit of the scheme.

Genesis Response

Again, this plot is the total amount of controlled discharge plus the natural inflows upstream of the Piripaua Bridge flow station. The natural flows originate from the Kahuitangaroa, Mangaone and leakage flows that enter the Power Scheme.



The plot below is very important, the flow at Piripaua Bridge, the last measurement point on the scheme, (that already includes a large portion of natural flow) was 90 m3/s. Only 4km's downstream from this point the flow was recorded as 170 m3/s at the Terapatiki flow station highlighting a very large increase in natural flows. This mirrors the rainfall totals that were very large in an already saturated catchment. The magnitude of flows seen in Wairoa township was less than 1% of the total flow recorded at the Piripaua Bridge.

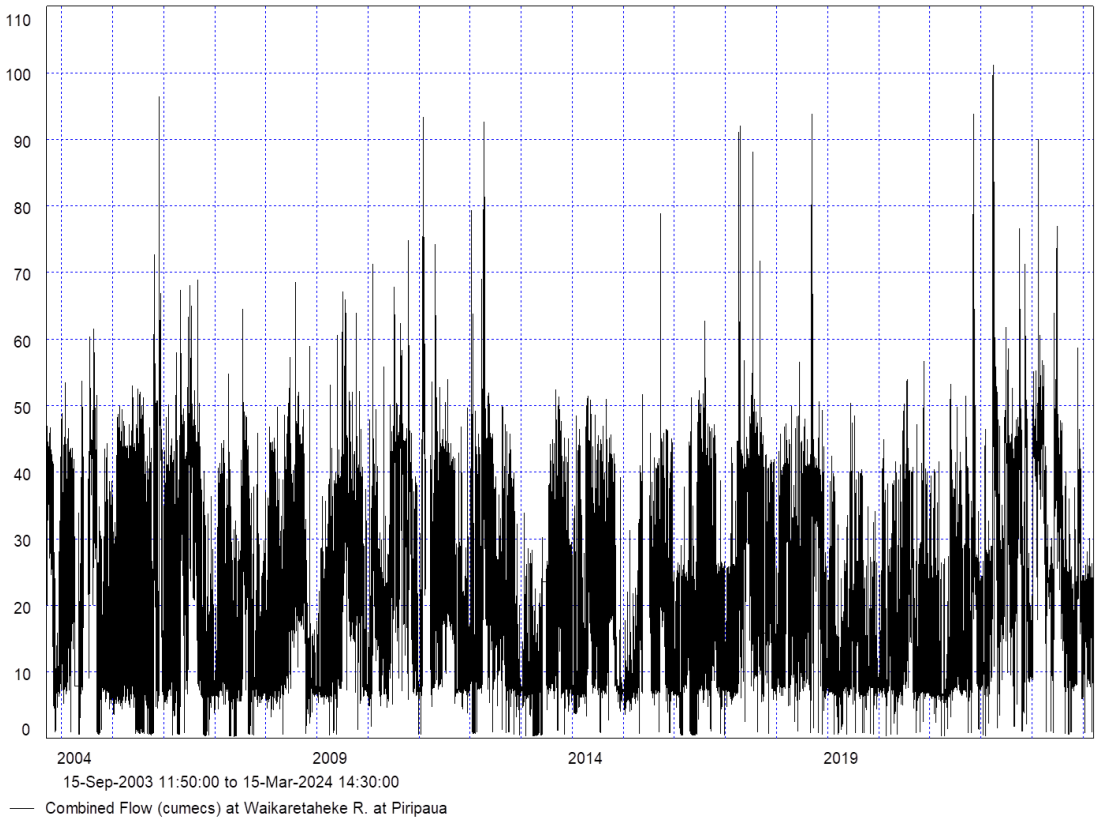


Review | Question 4

Over the duration of the flow record (since 1994??) the relative scale of those flows

Genesis Response

This data record starts in 2002 and is a combination of flow from the Piripaua Station and Piripaua Bridge. This provides more long-term context about the total discharge from the scheme when considering downstream flows. Total scheme discharges have been larger than the Gabrielle flows 10 times since 2003 (Cyclone Bola was larger again and occurred in 1988) showing that when large storms arrive, the scheme is hydraulically limited through its structures and simply cannot discharge large, controlled flows from Lake Waikaremoana.



Flooding in and around Home Bay Lake Waikaremoana

In response to the video of high lake level at the Kaitawa Intake and the photos of high levels at Home Bay, received on 15/3/2024.

The video at the intake reinforced what we spoke about during the site visit when we estimated the black marker located above the top of the orange MCL mark of 583.29m is approximately less than 1.0m high. The black cannot be seen in the video because of the high-water level. I assume the video was also taken on 10 Mar 2023 on the same day as the photos.

At that time, the lake level was 584.10m which is 0.81m above the Max Control Limit. It would have been just above the top of the black marker seen in the 'Kaitawa Intake at Onepoto Bay on Lake Waikaremoana' attached to this email. We have two sensors that show the recorded level is correct and the data goes through a stringent quality and auditing system.

The two Home Bay photos give an idea of flooding at these assets when 0.81m above MCL.

Attachment 4 | HBRC responses to questions

Initial questions submitted

From: andrew@stromeadvisory.com <andrew@stromeadvisory.com>
Sent: Monday, February 12, 2024, 2:53 PM

HBRC Staff Member	Issue	Question	Context
Craig Goodier	1.	I'm keen to have an HBRC estimate of the scale of the flood flows on the Hangaroa/Wairoa within the event probability range i.e. 1:50 – 1:100-year event as measured at the Riverina Bridge	Seeking to verify my sense of the scale
	2.	For the Wairoa Catchment - Rainfall is recorded as being highest at the Pukeorapa and Fairview Range gauges - firstly is there an ability to estimate the flow contribution (Kotare/Mangapoike) in proportion to the total peak flow at the Riverina bridge site? And further is there any estimate of the velocity of that flow contribution given nature of the sub-catchment - the very steep short run.	The flood waters are reported to have arrived very fast in North Clyde – the contribution from the Mangapoike/Kotare nearby may explain this in part
	3.	Is there a comparison of the flood flows through North Clyde as modelled in the HBRC Technical Report Wairoa River Flood Survey 2006 I note the scenarios presented suggested a 1:100-year event at the time however I appreciate the model has been substantially upgraded and the Lidar survey complete in 2020.	
	4.	Similarly, is there a comparison of the scale of the Gabrielle Event i.e. in flows (cumecs at peak) versus the estimated scale range of the 1948 flood in Wairoa, noting the 1948 estimate had a very wide range (as per Gary Clode's assessment in 1994).	The 1948 Flood event seems to be a much more useful comparator to Gabrielle than Bola

HBRC Responses

HBRC estimate of the scale of the flood flows on the Hangaroa/Wairoa within the event probability range i.e. 1:50 – 1:100 year event as measured at the Riverina Bridge

HBRC is not in a position to provide an estimate. MBIE has commissioned NIWA to conduct analysis of the flow rates and associated return periods for flooding in the Hawke's Bay region during Cyclone Gabrielle. We expect that this data will be finalised in the coming weeks.

For the Wairoa Catchment - Rainfall is recorded as being highest at the Pukeorapa and Fairview Range gauges - firstly is there an ability to estimate the flow contribution (Kotare/Mangapoike) in proportion to the total peak flow at the Riverina bridge site? And further is there any estimate of the velocity of that flow contribution given nature of the sub-catchment - the very steep short run.

Rainfall totals (NIWA), are shown in figure 1 below. No legend is available for this image. However, maximum values in red are approximately 500 mm. Figure 2 shows the long-term average, 24-hour rainfall totals for a 5-year event.

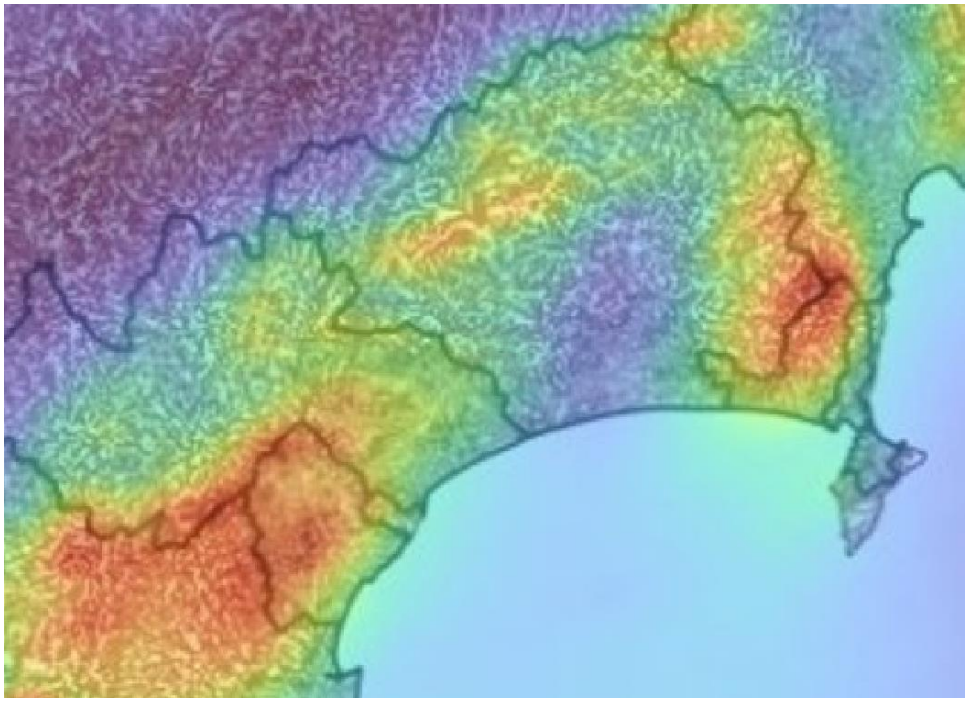


Figure 1. – Rainfall Totals (NIWA)

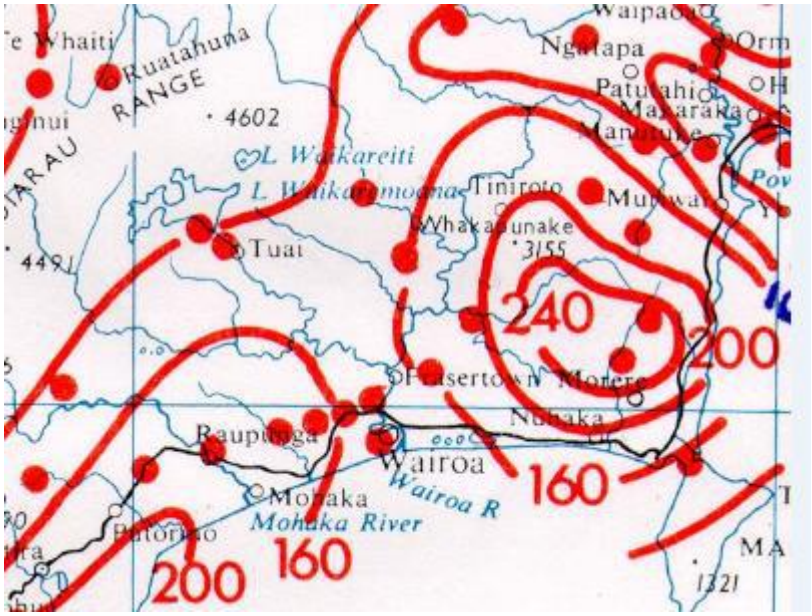


Figure 2. - Long-term average, 24-hour rainfall totals for a 5-year event

The locations of the Pukeorapa and Fairview gauges are in the high rainfall areas, as shown in Figure 3 below. This means that the distribution of rainfall does follow the topography and expectation of high rainfall areas. The flow contribution from Mangapoike was likely substantial. As shown in Figure 4, by area it is about 400 km2 out of 1800 km2 (at Marumaru). An estimate of contribution from that catchment may be made after the NIWA report is released. The timing of the flow contribution will be an implicit aspect of the flow measured further downstream.

Figure 3. – Rain Gauge Locations

Figure 4. – Wairoa Catchment Areas

Is there a comparison of the flood flows through North Clyde as modelled in the HBRC Technical Report Wairoa River Flood Survey 2006 I note the scenarios presented suggested a 1:100 year event at the time however I appreciate the model has been substantially upgraded and the Lidar survey complete in 2020.

The 2006 report showed 100-year flooding as below, in figure 5. Flooding in Gabrielle appeared to be less than shown in this image. The modelling undertaken for the proposed improvements will provide an update to the 2006 maps. This work is in progress but not yet published.

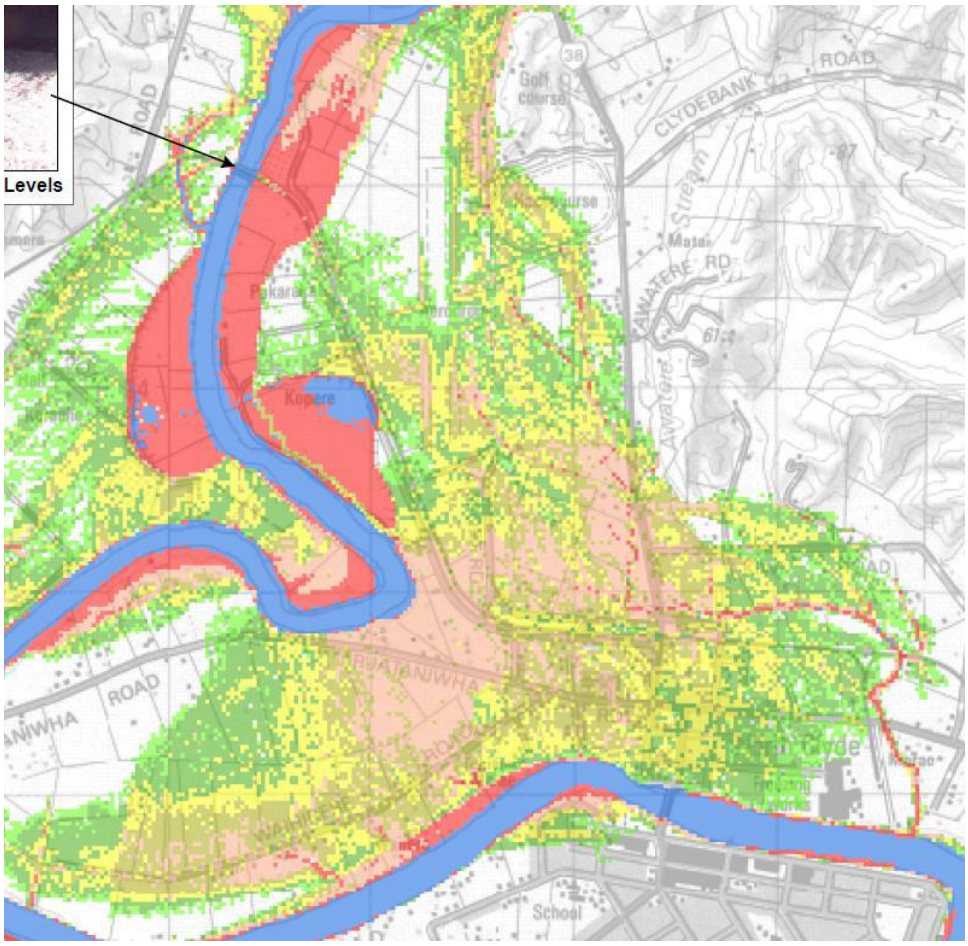


Figure 5. – 2006 Flood Modelling of a 1:100 year flooding event in Wairoa

Similarly is there a comparison of the scale of the Gabrielle Event i.e. in flows (cumecs at peak) versus the estimated scale range of the 1948 flood in Wairoa, noting the 1948 estimate had a very wide range (as per Gary Clodes assessment in 1994).

From 1994 report, the range of peak flow estimate is substantial.

i.e. **May 1948 Estimate** is - say - **8200m^3/s**
Estimation error is at least +/- 35% giving a range of 5300 to 11,000 m^3/s.

Once the NIWA estimates are available, a more in-depth analysis may be carried out.

Neighbours adjacent to the Wairoa Railbridge report a significant woody debris build up on against, on and adjacent to the bridge (ie embankment). Further commentary suggests a flow differential of (anecdotally) 1-2 metres in elevation between the upside and downside of the bridge at or near the peak flow. As per the Wairoa Community Stakeholder group process assessing flow mitigation options - I understand an allowance equating to 10 percent of the total flow is modelled as backflow – affecting farm properties upstream with 90% of the flow continuing down the mainstem and through the showgrounds – North Clyde area. This leads to 2 questions: - 1. without the bridge would the flows have remained within the mainstem? Or

would have North Clyde have flooded regardless ?– lidar levels and flow records will/have verified this presumably. 2. Pretty speculative I appreciate but is there any view as to the impact of the rail bridge blockage on flow velocity?

As demonstrated below in figure 6, the effect of blockage at the railway bridge would only have an effect of reducing the overflow into North Clyde. Imagine if the rail bridge could block a huge portion of flow and maintain the water in the channel (i.e., no out of channel flow). This would result in water arriving at the overflow into North Clyde at a slower rate and would result in lesser flooding. As a corollary, if there was no blockage at the rail bridge, the water would arrive at the North Clyde overflow earlier, and with a higher discharge, causing worse flooding.

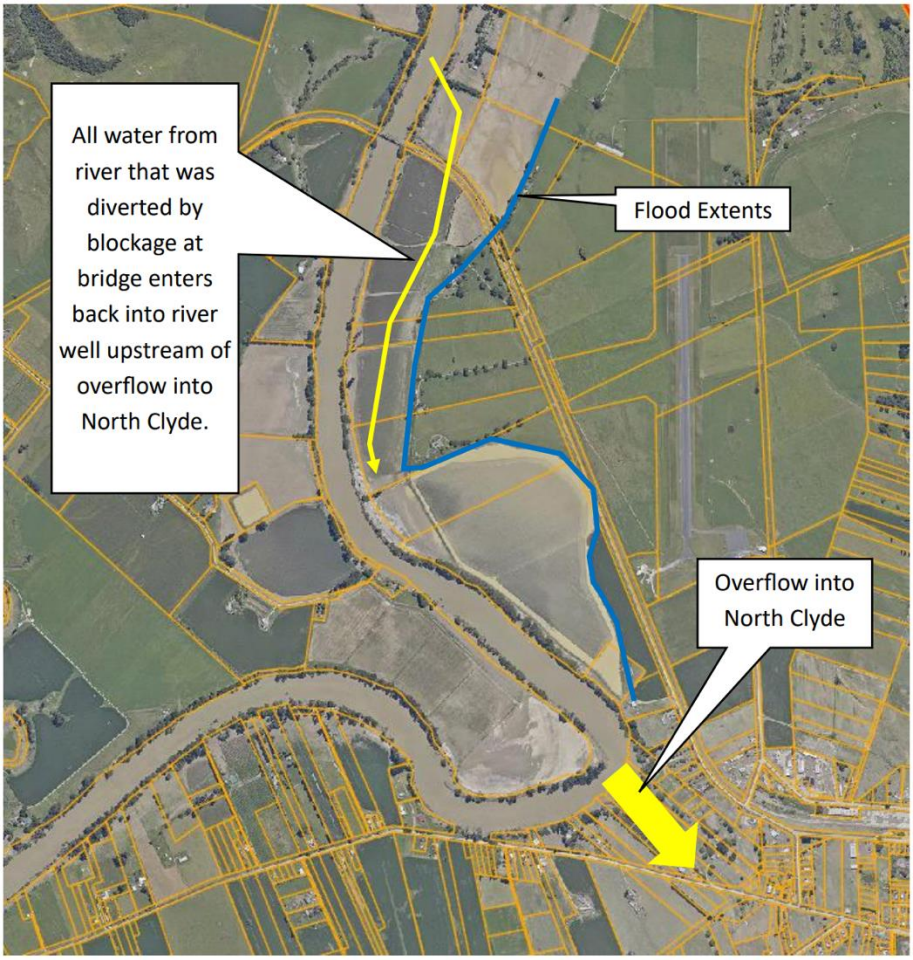


Figure 6. HBRC comments on North Clyde

To the extent possible it would be helpful to clarify tidal influences if any at around the rail bridge at peak flow.

At low flow, there is a tidal influence at the rail bridge, but this is overwhelmed quite early in flood conditions. This can be seen in the water level plot, with a clear tidal influence, which disappears with increased flow. When the peak water levels are say 10-12 m higher than the tide, the force and momentum of the river water coming down the channel is much greater than the

influence of a tide at about 1m. Conclusion – at peak flow, there is zero influence from the tide at the railway bridge.

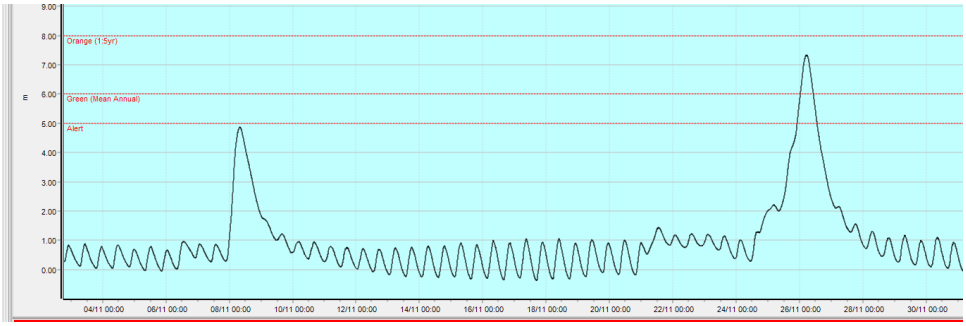


Figure 7.

I also note an independent report commissioned by Genesis quotes a peak flow at the rail bridge during Gabrielle as being 7901 cumecs - does this no. Come from hbrc and if so is it considered accurate?

I believe that was a preliminary value given out from HBRC using a rating curve at the railway bridge (relating water level to discharge). That rating curve has not been verified and there would be a caveat with the 7901 m3/s value as being an estimate based on limited information. The modelling for the proposed works will be able to provide an updated estimate, in line with the NIWA report.

Science Team Responses

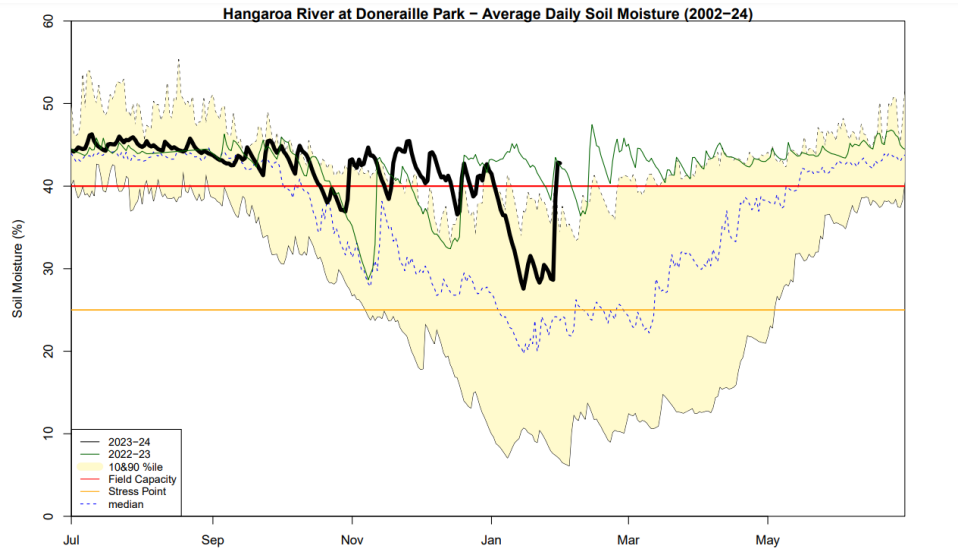
I'm keen to have the Doneraille Park monthly soil moisture statistics as per the graphical representation provided by Kathleen for the 2 years leading up to Gabrielle and for the 3 months after.

The requested data is in the Excel file attached. These are the daily averages, which are used to create the monthly numbers we use for our SOE reporting. Please also note our standard data disclaimer applies to this information:

Please note that the data provided has not been through a complete HBRC quality assurance process and is therefore subject to change following the completion of HBRC quality assurance processes, reviews or audits. The data provided and any statistics calculated from the data provided should be used with caution.

There is an explanatory note on our website regarding how we measure soil moisture, etc. This note is available here: https://www.hbrc.govt.nz/environment/climate/soil-moisture/

Also available on our website are the SOE reports which have all the sites in more detail with information on field capacity and stress point etc (see below). These are available on our website for all months completed. https://www.hbrc.govt.nz/environment/state-of-the-environment/soe-monthly-reports/



(Disclaimer: Field capacities at each site vary according to soil type and conditions. All field capacities are estimates only, and are based on patterns in historical data from each site.)

Follow-up Questions

1. What's the flow level WSP are designing to for peak flood design expressed in cumecs - Wairoa mainstem
1. The status of the Wairoa Flood Reserve
2. Just wondering if the chart showing soil moisture at Doneraille park as per the responses you me can have the 23/24 line either de-emphasised or removed, and the 22/23 line emphasised

HBRC Answers

With regard to the first question, I am advised:

The combined peak flows are summarised below accounting for the estimated timing effect and normalised flow distribution.

2. Climate Event AEP Simulated Peak Flow (m3 /s)
3. Current Climate (2023) 1% 6700
4. Future Climate (2110, RCP8.5) 1% 8600
5. Cyclone Gabrielle (estimated) - 6200

Note that flows estimated for RCP 8.5 represent an upper bound climate change scenario and are based on nationally averaged values, rather than region specific values. No national guidance is available for region specific application of projected climate change and is thus an area of high uncertainty.

Please also note that these figures are preliminary subject to NIWA work and any further work as necessary by HBRC.

Follow-up Questions

Really appreciate the rapid response –

However given the variance in the estimated no.s from those previously – i.e., shortly after Gabrielle provided to Genesis – 7,900 cumecs – which I thought was well on the high side given contributions from the Maraumaru flow site estimated @4,962 cumecs and Ardkeen @ 1,656 cumecs – and noting the slight but not material variations in the peak flow no.s for the tribs provided in a memo to Nick Peet by Kathleen Kozyniak - 4 September 2023 .

Can I assume that the modelling for the WSP flood protection project now has different Gabrielle peak no.s for Marumaru, Ardkeen etc and if so, what are they.

Can I also confirm that the WSP work fundamentally relies on the HBRC Wairoa flood flow model – the related flow gauging and weather station data as its basis.

Turning to the 'current' estimate of a 1% AEP for Wairoa – 6,700 m3 – this is a substantive variance from the previously prevailing estimate i.e. 8,200 m3 +- 35% - is there an underlying logic to this which is simply explanation.

HBRC Response

1. The answers to your questions from 7 March. I note that these pre-dated the availability of the NIWA data, so may have been overtaken by events,
2. The answer to the question your question following the NIWA data, which you chase below.

I note that we are also working on the revised chart showing the moisture levels at Doneraille Park. We'll come back to you with that as soon as possible.

One - 7 March Questions and Answers

Can I assume that the modelling for the WSP flood protection project now has different Gabrielle peak no.s for Marumaru, Ardkeen etc and if so, what are they.

To simulate Cyclone Gabrielle and to assist in the derivation of WSPs flood frequency analysis, we have used peak flows of 4700m³/s in the Wairoa (at model boundary) and 1700m³/s in the Waiau (at model boundary). The peak in the Waiau was estimated to have occurred around 2.25hr after the peak in the Wairoa. A combined peak discharge of 6200m³/s has been used, allowing for timings.

Can I also confirm that the WSP work fundamentally relies on the HBRC Wairoa flood flow model – the related flow gauging and weather station data as its basis.

A series of new hydraulic models have been generated for this work, based on historic and new river cross-sections, recent aerial LiDAR, and bridge as-builts.

WSP's estimate of Cyclone Gabrielle and design flows is based on a combination of HBRC flow/ water level gauges on the Waiau and Wairoa rivers, aerial photography, and local photography. Consultation has occurred with NIWA and HBRC for both this project and a parallel NIWA project. Deviation from the initial estimated flow from Cyclone Gabrielle has occurred, as the original estimates would have required excessive scour (>4m) to have occurred within the Wairoa channel downstream of the KiwiRail Bridge to match records.

Turning to the 'current' estimate of a 1% AEP for Wairoa – 6,700 m3 – this is a substantive variance from the previously prevailing estimate i.e. 8,200 m3 +- 35% - is there an underlying logic to this which is simply explained?

To put this in perspective, the new (6700m³/s) 1% estimate is within the standard error of the initial estimate. It is also 2000 m³/s greater than estimated by NIWA's 2018 Nationwide flood statistics work.

The Wairoa River is relatively flat, largely under the sea level up to Frasertown, and affected by the bar at the mouth. It is possible that original estimates from the 1990s overestimated the capacity of the river.

Two - Follow up question

"Only one question – and that is concerns the WSP view on the gauging data at Maramaru – HBRC 4960 cumecs approx. vs 4,100 cumecs in the WSP model – a simple plain English explanation of why this is adjusted this would be good."

The Wairoa at Marumaru gauge rating curve was updated following high flows in early 2022 (see figures below). We believe that due to sediment and debris in the river and the fact that the flow recorder is near a bridge structure, the new rating curve may have overestimated the flows. The flows reported by NIWA, as estimated by WSP, fit between the old and new rating curves and were chosen after significant calibration to flood extents and estimates of bed scour within the Wairoa Channel. As with any low probability hydrology estimates, there is a high margin of uncertainty.

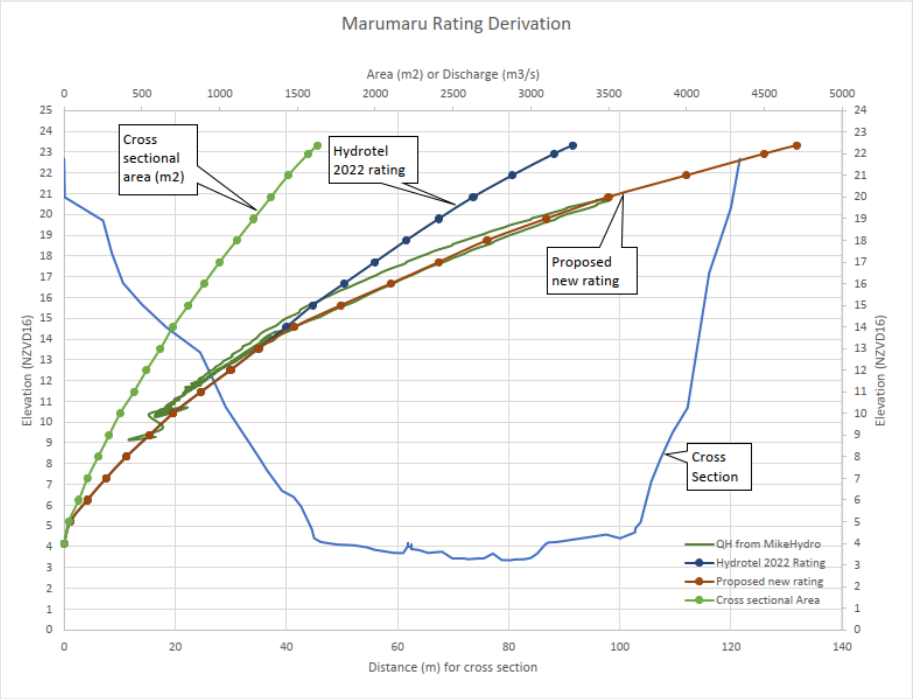


Figure 1. Figure from 20220505_Wairoa_at_Marumaru_Rating_Proposed_Adjustment, HBRC, 2022. Old rating curve in blue, HBRC 2023 rating curve in maroon.

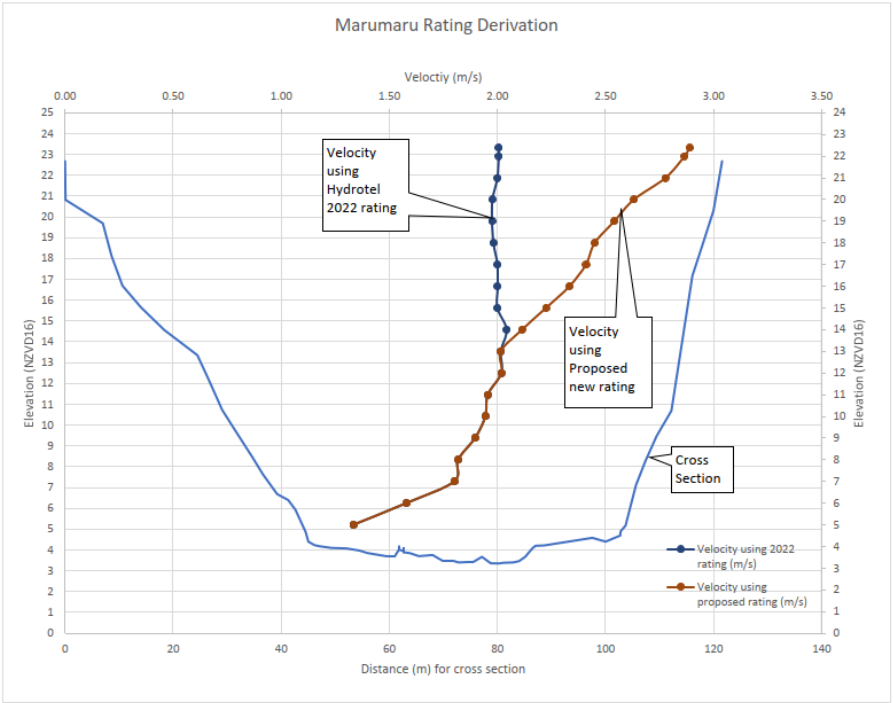


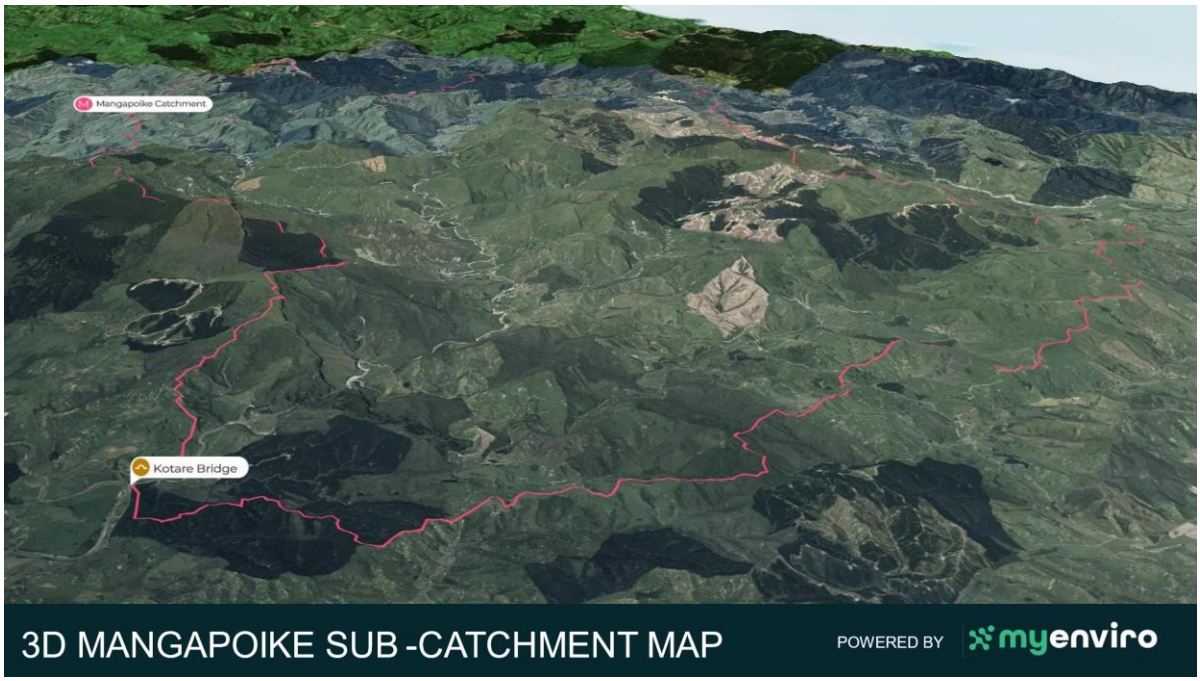
Figure 2. Figure from 20220505_Wairoa_at_Marumaru_Rating_Proposed_Adjustment, HBRC, 2022. Old rating curve velocity in blue, HBRC 2023 velocity rating curve in maroon.

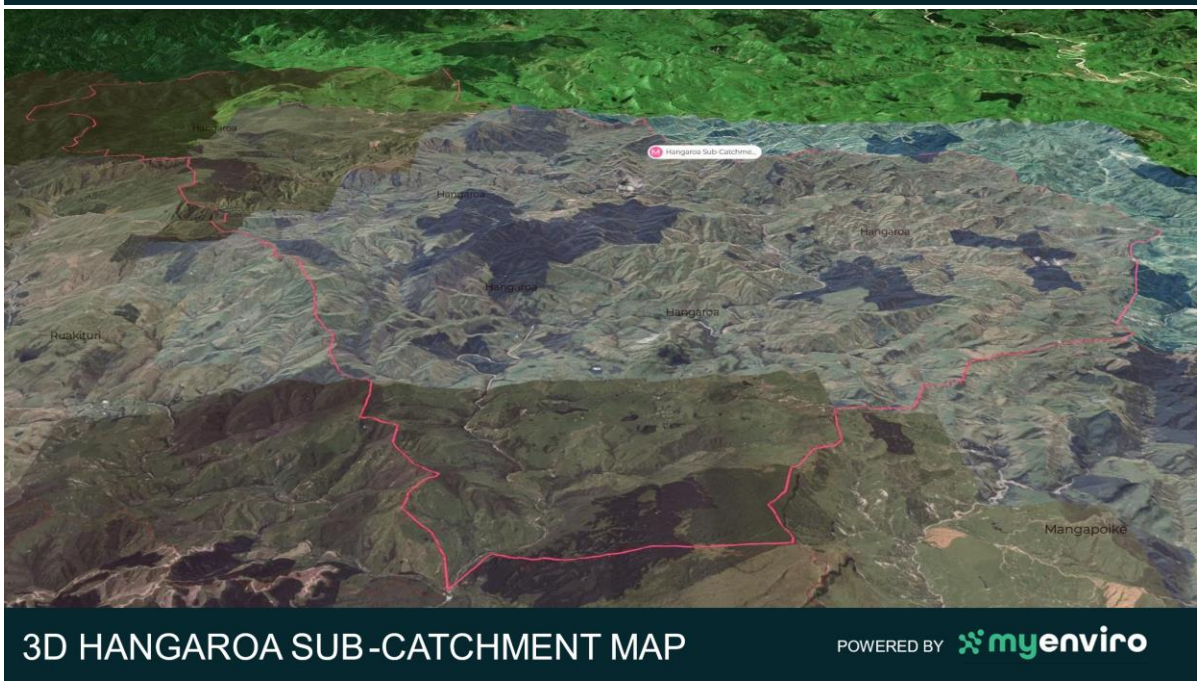
The team are working on a response to the follow up on peak flow numbers. I'll get that to you ASAP. Same for the revised soil moisture data.

With regard to the Wairoa Flood Reserve, I am advised as follows:

- A reserve was created in 2002 called Wairoa Rivers and Streams, with the purpose being to fund flood mitigation and recovery work within the Wairoa District.
- HBRC has diligently added to the reserve over the years, including interest.
- In 2004 (or thereabouts) HBRC created a scheme called Wairoa and Northern Streams, which is a district-wide scheme, expressly for the purpose of undertaking vegetation clearance in streams and rivers in the Wairoa District. There was to be no capital component to this scheme.
- There have been a number of flood mitigation activities that HBRC have funded in Wairoa over the last 20 years, including rock walls, sheet pile walls tree clearing and river management. These have all been erroneously funded from the Wairoa and Northern Streams scheme reserve, which is now in deficit by around $784k.
- The Wairoa Rivers and Stream reserve has been untouched since its creation and has a surplus balance of $1.075m.
- Over the last 20 years HBRC has funded $1.145m of works directly in the Wairoa District. Given that $336,372 of this figure was a HBRC 25% contribution to IRG-funded projects, then the total amount of work completed over this period was $2.49m ($1,345,488 – total IRG funding including HBRC contribution).
- HBRC is now looking to transfer funds from the Wairoa Rivers and Stream reserve to the Wairoa and Northern Streams reserve to clear the deficit incorrectly incurred in this reserve. This will leave around $200k remaining in the Wairoa Rivers and Stream reserve. However, this transfer will require the approval of council.

Attachment 5 | 3D Maps of Northern Wairoa Catchments





Attachment 6 | Comment on Woody Debris surveys

Q1: Brief review of forestry group woody debris Hawke's Bay report as it relates to Wairoa Catchment specifically – observations on method if relevant

There were two reports commissioned to evaluate post-Cyclone Gabrielle woody debris in Hawke's Bay. These are:

- Ecological Solutions Report prepared for HBRC on *Cyclone Gabrielle Woody Debris Species Composition Assessment*.
- Interpine Innovation Report prepared for Hawke's Bay Forestry Group *Cyclone Gabrielle Post Event Woody Debris Assessment – Hawke's Bay*.

Both reports cover the Mohaka and Wairoa River mouths. The Interpine report also covers the Waihua River.

The HBRC slash report uses a hybrid method based on Cave's (2023) Large Woody Debris Assessment Guide. V.2.1. The Cave method is a simple count based on squares and transects. Both the Cave and Ecologic reports are weak on statistical validation of the method and do not describe how bias is removed, e.g., the selection of initial plot location. The Ecological report tries to estimate volume. The method relies on counting numbers of debris and using an eyeometer method to adjust the size distribution of the pieces to a relative difference in volume to offset the potential risk that a few large pieces may be overrepresented in volume but underrepresented in piece counts within the same plot or pile. For example, the plot may have 49 small pine pieces and one large willow. Pine would account for 98% of the wood pieces but may only be 10% of the overall volume. The method is, therefore, a quantitative and qualitative assessment. The report provides good confidence in the mix of the debris by a piece type count but low confidence in volume results. Some of the report's text and graphs were confusing because of lack of clarity around whether it was discussing volume or number of pieces.

The Interpine report has a much more robust sampling methodology and provides more detail. Interpine's business centres on providing statistical assessments to forestry companies on their forest resource. The method Interpine chose for the debris assessment has a proven sampling methodology dating back to the 1970s in New Zealand for calculating the residual wood left on harvesting cutovers (Wagner waste assessment, 1968). Over the decades, the method has refined to remove bias and improve precision. It has been adapted worldwide. The approach provides an estimate of volume based on debris diameter. The report provides

strong confidence in the results. The Interpine report went outside the scope of assessing woody debris volumes to provide recommendations and general discussion on woody debris.

The two reports do not use the same classification to describe the differing types of debris. However there is enough similarity to compare the differences between the report findings.

The key graphs in the report were:

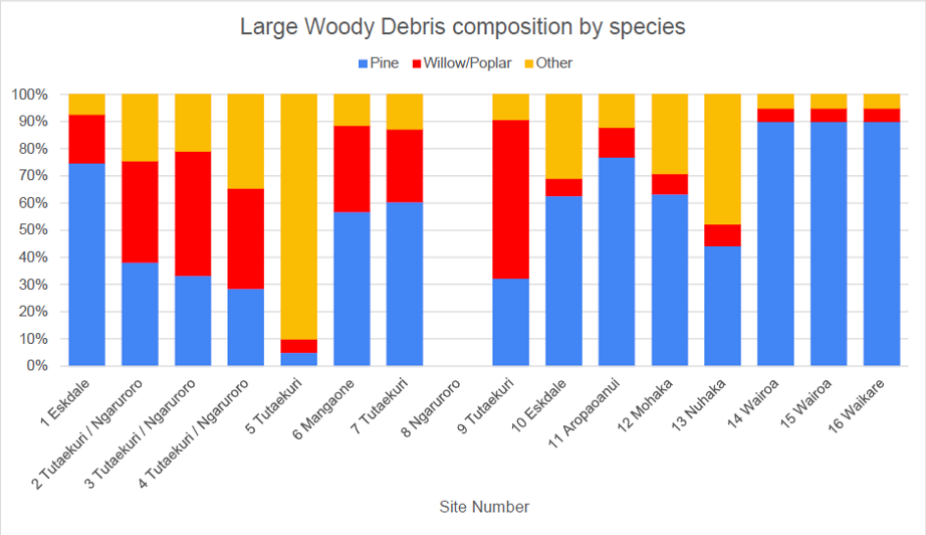
Interpine

	Plantation Pine/Conifer									
Average m3/ha as %	Pine/Conifer OTHER	Pine/Conifer FULL TREE	Pine/Conifer HARVEST SLASH	Pine/Conifer OLD PINE	POPLAR WILLOW	NATIVE	EUCALYPT	POST/TIMBER	OTHER	TOTAL m3/ha
Aropaoanui River	26%	12%	5%	1%	48%	4%	0%	0%	4%	429
	43%			57%						
Esk River	37%	21%	4%	5%	23%	5%	0%	1%	4%	441
	61%			38%						
Mohaka River	45%	22%	7%	0%	6%	18%	0%	1%	2%	470
	73%			27%						
Ngarururoro / Tutaekuri River	25%	5%	6%	2%	52%	2%	0%	3%	4%	428
	36%			64%						
Tukituki River	0%	0%	1%	0%	98%	0%	0%	0%	0%	301
	1%			99%						
Waihua River	35%	3%	3%	0%	41%	12%	0%	5%	0%	661
	42%			58%						
Waikari River	74%	13%	2%	0%	6%	3%	0%	2%	0%	601
	89%			11%						
Wairoa River	13%	14%	2%	0%	36%	29%	0%	1%	7%	762
	29%			71%						

Average Volume per Hectare by location and debris types

The percentage of forestry slash is low, around 2% of the overall woody debris volume. Slash is described as plantation harvest residue or wood that shows evidence of flush cuts/slovens/processor damage/branches cut off/cut stumps.

Ecological



**Note the Wairoa River mouth was an estimate based on a flyover only.*

Wairoa River Mouth

The following are quotes taken from the reports:

Interpine

'Plantation pine/conifer accounted for 29% of the total Wairoa survey volume per hectare (219 m3/ha), with the highest classification being poplar/willow at 36% (271 m3/ha), and native with 29% (218 m3/ha). Pine/conifer harvest slash accounted for 2% of the total Wairoa survey volume per hectare (16 m3/ha).'

'The Wairoa catchment woody debris deposition was measured to be 51.9 ha. Two plots were measured, representing a plotting intensity of 26 ha per plot of mapped woody debris. Plots show an average of 762 m3/ha in the woody debris piles mapped across the region with a PLE of 776.7%.'

'The report stated 'Wairoa River mouth was found to have the highest proportion of indigenous woody debris out of any catchments measured. Another notable observation regarding the Wairoa mouth was the prevalence of material that appeared to be aged (Figures 4 and 5). This may have been debris brought down that was lodged in the upper catchment from a previous event(s).'

Ecological

'Unfortunately, no suitable and safe landing location was available, so this site was not able to be assessed using quantitative methods. The site was therefore assessed using the qualitative visual estimation of percentage volume methodology. It is recommended that this site is revisited and assessed quantitatively once access is safely obtainable.'

'The proportion of pine, willow/poplar and other species in the woody debris accumulation at the bridge was visually assessed as comprising 90%, 5% and 5% respectively.'

Attachment 7 | example of a poorly managed harvest site

Attachment 8 | Forest slope failure Gisborne District - Gabrielle