Kerikeri-Waipapa River Working Group

Thursday 27 March 2025 at 10:00am - 11:30am

AGENDA

Northland REGIONAL COUNCIL

Te Kaunihera ā rohe o Te Taitokerau

Kerikeri-Waipapa River Working Group Agenda

Meeting to be held in the NRC Waipapa Office, 12 Klinac Lane on Thursday 27 March 2025, commencing at 10:00am - 11:30am

Please note: working parties and working groups carry NO formal decision-making delegations from council. The purpose of the working party/group is to carry out preparatory work and discussions prior to taking matters to the full council for formal consideration and decision-making. Working party/group meetings are open to the public to attend (unless there are specific grounds under LGOIMA for the public to be excluded).

MEMBERSHIP OF THE KERIKERI-WAIPAPA RIVER WORKING GROUP

Chairperson, Councillor Joe Carr

FNDC Councillor, Steve McNally	BayCare, John Dawn	Iwi representative, Hugh Rihari
Iwi Representative, Hone Tiatoa	Upper Kerikeri Catchment, Hamish Sheard	Lower Puketotara and Kerikeri Catchment, Fred Terry
Upper Puketotara/Waiwhakarongaro Catchment, Murray Wright	Business Community Representative, Tony Corcoran	

RĪMITI (Item) **Page**

TITLE:	**Record of Actions – 19 September 2024**
From:	Haylee Labelle, Personal Assistant Community Resilience
Authorised by Group Manager/s:	Louisa Gritt, Group Manager - Community Resilience, on 20 March 2025

Whakarāpopototanga / Executive summary

The purpose of this report is to present the Record of Actions of the last meeting (attached) held on 19 September 2024 for review by the meeting.

Attachments/Ngā tapirihanga

Attachment 1: Record of Actions ⇩

Kerikeri-Waipapa River Working Group Record of Actions

Meeting held in the NRC Waipapa
12 Klinac Lane
on Thursday 19 September 2024, commencing at 10:00am

Tuhinga/Present:

Chairperson, Councillor Joe Carr
FNDC Councillor, Steve McNally (virtual)
BayCare, John Dawn
Iwi representative, Hugh Rihari
Lower Puketotara and Kerikeri Catchment, Fred Terry
Upper Puketotara/Waiwhakarongaro Catchment, Murray Wright

I Tae Mai/In Attendance:

Full Meeting
NRC CE, Jono Gibbard
NRC Councillor, Geoff Crawford
NRC Councillor, Marty Robinson
NRC Councillor, John Blackwell (virtual)
NRC Secretariat, Haylee Labelle
NRC GM Community Resilience, Louisa Gritt
NRC Rivers Project Manager, Meg Tyler
NRC Rivers and Natural Hazards Manager, Joseph Camuso
Dennis Corbett
Jonathan Cousins

Part Meeting
Richard Civil (left 10.49am)
Jo Civil (left 10.49am)

The meeting commenced at 10am with karakia by Hugh

Ngā Mahi Whakapai/Housekeeping (Item 1.0)

Ngā Whakapahā/Apologies (Item 2.0)

Moved: (Robinson / Crawford)

Iwi Representative - Hone Tiatoa, Upper Kerikeri Catchment - Hamish Sheard, Business Community Representative - Tony Corcoran, Cr. Ann Court (FNDC), Cr. Tui Shortland (NRC), Cr. Amy Macdonald (NRC), Cr. Jack Craw (NRC), Cr. Rick Stolwerk (NRC), Cr. Peter-Lucas Jones (NRC), Jacqui Hori-Hoult (NZTA), Bronwyn Bauer-Hunt (DOC), Tyler Bamber (FNDC), Belinda Ward (FNDC), Cath Lawson (NRC), Murray McCully, PK Engineering

Kerikeri-Waipapa River Working Group
19 September 2024

Record of Actions – 21 March 2024 (Item 3.1)

Presented by: NRC Secretariat Haylee Labelle

Agreed action points:

- Record of actions has been confirmed with no amendments

Receipt of Action Sheet (Item 3.2)

Presented by: NRC Secretariat Haylee Labelle

Agreed action points:

- **Action 4, 12/3/24 to be marked as completed as Meg Tyler had the consultant breakdown available at the meeting as a handout**

Detention Dam (Item 3.3)

Presented by: John Dawn & Joe Carr

Refers to email sent by John Dawn 18/9/24 (circulated to members and copies at meeting) and PK Engineering document "Blueprint One – An integrated concept for future development of Kerikeri and Waipapa 2025-2050" (circulated to members and copies at meeting).

The chair acknowledge the work PK has undertaken and the contribution he has made

This would be a detention dam above SH10 to mitigate storm events, with 8m tall dam face, 4 million m2 of excavation aimed to reduce flooding around Puketotara capable of 300mm in 24hrs storm event

Feedback: This is a beginning stage idea, struck by the enormity of the earthworks required; the excavated materials cannot be used for bund construction (where will it go and what will it cost – will require resource consent to take elsewhere) concerns about rate payer $ for investigations, Property has basalt pinnacles unsure of concerns when excavating. Complexity added by weirs makes this an active system (not passive). Want to define the risk more using new flood mapping. The 8m bund along SH10 somewhat imposing and would trigger it as a high PSE category e.g. needing dam break analysis. The flood mapping we have now uses 280mm over 12hrs. Scaling back wouldn't give 100yr protection but could achieve some outcomes

Agreed action points:

- **NRC to do work in-house to follow John Dawns recommendations and answer questions**
- **To identify critical elements of the project to pass checks / identify fatal flaws**

Kerikeri Flood Model Update (Item 3.4)

Presented by: Joe Camuso

Flood modelling will identify downstream risk, we have bought this forward. We need to bring in updated LiDAR to update the flood maps which will be available to the public

Agreed action points:

- None

Any Other Business (Item 3.5)

Presented by: Joe Camuso

Riley dam – circulated Riley report following last hui "proposed Kerikeri K3A dam concept design and costing" when this was done initially we did not have a full LiDAR which is worth modelling to move on with the project and produce new flood maps then we can identify where the risk is and take the next steps.

Discussion was had around emphasis on river work in terms of subdevelopments.

Agreed action points:

- **To update flood models for K3A and make assessment of the risks – Joe Camuso**
- **Fred Terry would like information on the discharge of Puketotara/Kerikeri into the basin area (Stone Store) total effect of an in excess 100yr event – Joe Camuso to provide data**

Whakamutunga (Conclusion)

The meeting concluded at 11.42am with karakia by Hugh.

TITLE:	**Receipt of Action Sheet**
From:	Haylee Labelle, Personal Assistant Community Resilience
Authorised by Group Manager/s:	Louisa Gritt, Group Manager - Community Resilience, on 20 March 2025

Whakarāpopototanga / Executive summary

The purpose of this report is to enable the meeting to receive the current action sheet.

Nga mahi tutohutia / Recommendation

That the action sheet be received.

Attachments/Ngā tapirihanga

Attachment 1: Action Sheet ⇩

Kerikeri-Waipapa River Working Group - Action Tracker

Action #	Meeting date	Item	KRWG action	Responsible staff	Status	Notes
3	12/03/2024	Receipt of Action Sheet (Item 3.2)	FNDC to prepare shovel ready business case for regional development funding requirements	Pradeep	**Complete**	Dam was impractical
6	12/03/2024	The Riley Upper Kerikeri storage/detention dam (Item 3.5)	To incorporate NRC and Pradeep's concepts into a presentation and present to NRC's CE, Community Resilience GM, and Cr. Joe Carr	Pradeep & Joe Camuso	In Progress	**4/3/25** Have not yet received **5/9/24** Louisa and Joe met with Cr Carr and discussed. Awaiting flood update model
1	19/09/2024	Receipt of Action Sheet (Item 3.2)	Action 4/12/3/24 to be marked as completed as Meg Tyler had the consultant breakdown available at the meeting as a handout	Haylee Labelle	**Complete**	
2	19/09/2024	Detention Dam (Item 3.3)	NRC to do work in-house to follow John Dawns recommendations and answer questions about Detention dam concept from PK Engineering	Joe Camuso	**Complete**	Report was circulated to chair and working group
3	19/09/2024	Detention Dam (Item 3.3)	To identify critical elements of the Detention Dam project to pass checks / identify fatal flaws	Joe Camuso	**Complete**	
4	19/09/2024	Any other business (Item 3.5)	To update flood models for K3A and make assessment of the risks	Joe Camuso	In Progress	**4/3/25** Awaiting model from Water Tech
5	19/09/2024	Any other business (Item 3.5)	Provide to Fred Terry, information/data on the discharge of Puketotara/Kerikeri into the basin area (Stone Store) total effect of an in excess 100yr event	Joe Camuso	In Progress	4/3/25 exploring this with Matt Jolly and if unable to undertake will reach out to Water Tech

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

11 November 2024

Peer Review of the Multi-Purpose Dam Proposal: "Blueprint One"

AN INTERGRATED CONCEPT FOR FUTURE DEVELOPMENT OF KERIKERI AND WAIPAPA 2025 - 2050

Overview

This peer review aims to evaluate PK's "Blueprint One" proposal for a multi-purpose dam that encompasses flood detention, hydrogeneration, water storage, and recreational use. The proposal of "Blueprint One" aims to mitigate flood risks, enhance water supply, and provide renewable energy, addressing concerns exacerbated by climate change. This is an ambitious proposal and part of the peer review is to identify feasibility.

NRC commissioned Toby Kay to review the Hydrology and provide a peer review of hydrology assessment report, which is attached to this for reference.

Technical Feasibility Assessment

1. **Geotechnical Considerations**

From my interpretation of the proposal, the dam would require a minimum of 4 million cubic meters of cut to excavate the reservoir. On a very conservative assumption that "all" the material was suitable for use in the Dam construction and using very favourable rates received from local contractors of $20 per Cubic Meter cut-to-fill short haul: 4,000,000 cm x $20 per cm = $80,000,000. Local knowledge from a landowner indicated that there are areas of "unsuitable" material and swampy areas within the dam footprint.

2. **Construction Feasibility**

The requirement for substantial earthworks raises questions about material handling and the stability of excavated slopes. The Dam will be classified as a high potential impact classification (PIC) dam under New Zealand Society of Large Dams (NZSOLD) Dam Safety Guidelines 2023, this would impose the most stringent design and material quality standards.

3. **Hydrology and Hydraulic Analysis**

A detailed hydrological study is essential to determine if the proposed detention volume will effectively manage downstream flood peaks. However, a multi-purpose dam is always a compromise between flood detention and water storage. From a flood management perspective, passive operation i.e., the dam is always ready for a flood no human intervention is needed, is preferred. The proposal outlines a series of weirs and sluice gates to deliver water from both the Kerikeri and Puketotara Streams to the Dam. This makes the management of the dam a "dynamic operation" adding complexity, human intervention and additional failure mechanisms to the operation of the dam. A more thorough Hydrological Analysis has been completed by Toby Kay and should be read in conjunction with this report.

4. Flood Mapping Upgrade

New flood mapping for Kerikeri Catchment has been commissioned. This will include the latest LiDAR and recent flood mitigation works to reduce flood risk to the Waipapa Industrial Estate area. This will be a good starting point to identify the flood risk to the area and areas of residual flood risk.

5. Conclusion

Overall, "Blueprint One" presents an aspirational approach to addressing flooding issues in Kerikeri-Waipapa. However, a rough order costing of just the earthworks in a "best-case" situation is estimated at $80 million. The full cost of the project could be double the $80 million with land-purchase, Iwi engagement, preliminary design, peer-review, detailed design, lawyers' fees, resource consenting, construction and easements. The cost on its own merit would make this proposal unstainable for Kerikeri residents.

I trust this information is useful.

Ngā mihi:

Joseph Camuso
Northland Regional Council
Rivers Manager

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Private Bag 9021, Whangārei 0148

28 October 2024

Review of the Multi-Purpose Dam Proposal: "Blueprint One": Hydrological Analysis

AN INTERGRATED CONCEPT FOR FUTURE DEVELOPMENT OF KERIKERI AND WAIPAPA 2025 – 2050

Scope of this Review:

The scope of this review is based on recommendations made to the Kerikeri Waipapa Flood Committee on hydrological investigations needed to assess the technical feasibility of the PK Engineering (PKE) Blueprint One proposal (Sept 2024). It is recognised this proposal is still at early concept stage, and there are a number of different aspects to be considered. The purpose of this review is to assess the feasibility of the proposal from a hydrological and flood management perspective. Specifically the brief includes the following tasks.

1. A quick and approximate analysis by a senior hydrologist to estimate the volume of flood detention required and appropriate elevations. This should be based on previous output from the catchment model. Specifically the analysis seeks to address:

   Q1 What detention volume is required at the proposed dam location to effectively reduce flood peaks downstream?

   Q2 What temporary storage elevations are appropriate?

   Q3 Can effective flood detention be provided with less earthworks?

   Q4 What inlet and outlet flow controls are required?

   Q5 Can control be achieved with passive structures or are active controls needed?

2. if indicated by the hydrological analysis, provide commentary on adjustments to the ponding area and elevations.

The hydrological analysis is to assess whether the proposed detention volume and bund elevation proposed at the dam site will effectively reduce flood peaks downstream. It is understood that if the proposal progresses beyond concept stage, then further analysis will be undertaken using the new TUFLOW catchment flood model (under development), but an approximate calculation is appropriate at this stage based on outputs from the existing DHI catchment model and other available data.

The PK Engineering Concept Proposal

The concept proposal includes excavation of a large basin area, approximately 100 – 110 Ha (1km^2) on the Southwest side of the Waipekakoura (Kerikeri) River upstream of the SH10 as shown in PKE report, Appendix A drawing A3/BP1-S3. The basin area is proposed to be bunded to provide for a permanent lake (Lake Waipapa) with standing water level at RL 72m and flood detention between RL 72m to RL 80m. The base of this lake is proposed to be at an RL 68m with a depth of approximately 4 metres and stored volume of approximately 4 million cubic metres when not being used for flood detention.

A formed bund up to 8 metres high with crest level of RL 80m would fully encircle the lower areas of the lake to provide an estimated additional volume of 10.4 million cubic metres for temporary flood storage. The total flooded area at maximum lake level under flood condition is estimated at approximately 150 hectares. The formed bund is to have a low batter slope of 8-10 degrees (ratio 1:6 - 1:7) so that the landform appears naturally formed.

A system of weirs and sluice gates is proposed to divert flood flows into the flood detention basin, and discharge flows from the basin via a new box culvert under the SH10 with capacity for 200 m^3/s. Downstream of the SH10 flows will follow a formed channel through 1878 SH10 to a new steady head reservoir located above a large waterfall at the East end of 1828 SH10. This reservoir will supply a hydro power station located below the falls. Inclusion of sluice gates at the outlet to Lake Waipapa would presumably allow the water level within the lake to be regulated, to supply the hydro-electric facility, or for water supply. This implies that standing water level could be above or below RL 72m depending on what volume of water was allocated for these dual functions. This review has assumed standing water level is RL72m.

Proposed flood inflows to Lake Waipapa are as follows:

i) Kerikeri River at North end of Waipapa Industrial Estate: Flood flows in excess of 200m^3/s (from catchment A)

ii) Puketotara Stream upstream of SH10 bridge: Flood flows in excess of 200 m^3/s (from catchment B)

iii) Maungaparerua Stream will flow directly into the basin area, therefore 100% of flow volume will be detained, and routed to the proposed box culvert outlet under the SH10.

The combination of the above measures is intended to limit upper catchment flows passing the SH10 to 600m^3/s, including 200m^3/s through each of the existing SH10 bridges, and an additional 200m^3/s through the proposed box culvert/s at the lake outlet.

The Blueprint One proposal envisages that the scheme will mitigate flood risk East of the SH10, as well as in the Waipapa Industrial estate, so that catchment overflows to Waipapa Stream are eliminated and that the downstream catchments G, F & H can be developed maximally without creating additional flood hazard in the Lower Waipekakoura / Kerikeri River. The proposal aims to provide new recreational areas, increased security of water supply, renewable energy sources, and approximately 3,000 more homes made possible due to the availability of flood free land.

Technical Feasibility Assessment

1. Hydrological Considerations

Flood detention design requires consideration of rainfall volumes, flows (including by-pass flows), spillway capacity and storage volume. Generally there are trade-offs that can be made during the design process to optimise the performance of a detention basin, for instance if inflows can be reduced, or outlet capacity increased, this would potentially allow for some reduction in storage capacity without compromising performance. Alternatively these adjustments could allow for the level of flood protection in extreme events to be increased.

At this early concept stage it is only possible to make rough estimates of detention volume based on reported lake surface areas and assumed elevations. However, given the proposed surface area of the detention basin is substantial, the available volume for flood attenuation can be estimated without likelihood of significant error, assuming the surface areas provided in the PKE report have been assessed reasonably accurately. Lake surface areas have not been verified as part of this review.

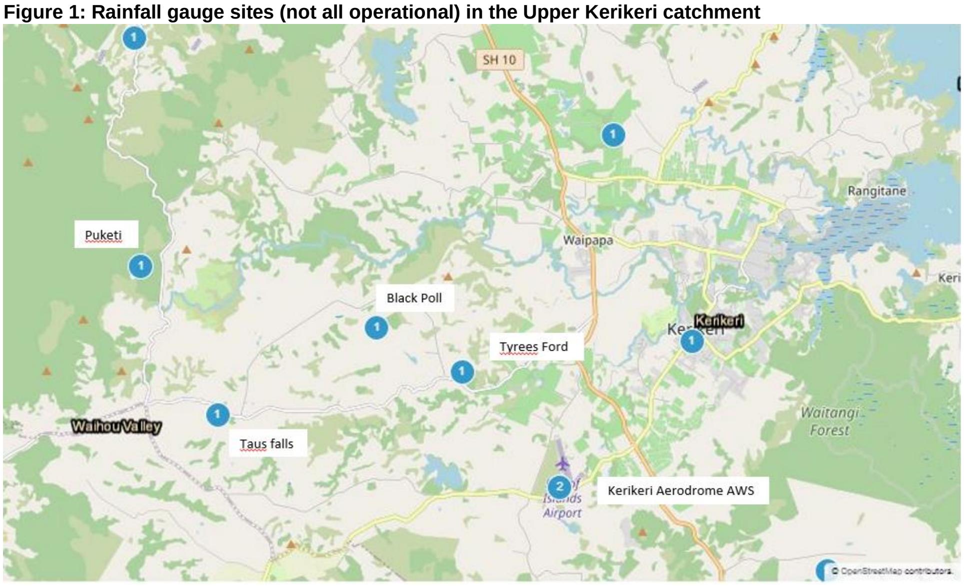
2. Design Rainfall

Commentary on the rainfall data used to assess flow volume estimates is provided in section 2.1 – 'Risk Profile' of the PKE report. It is stated that 24hr rainfall depths taken from NIWA data, allowing for climate change, are in the range 280mm – 300mm for a 1% AEP event in the Kerikeri and Puketotara catchments. Due to more extreme events that have occurred elsewhere, runoff volumes in the PKE report are based on scaled up rainfall depths of 350mm in a 24-hr period. The reference to Cyclone Gabrielle in the PKE report, and the potential for such events to impact the Kerikeri catchment is a valid observation. This is discussed further in section 4 below on over-design events.

Like many Councils, NRC relies on HIRDS[1] data as the basis for design storms used for flood modelling and flood scheme assessment. NIWA produces updates to the HIRDS package at least every 10 years. The current version is HIRDSv4 (released 2018), whilst the rainfall inputs to the Kerikeri catchment model are based on HIRDSv3 (released 2009). NIWA is currently developing HIRDS v5 which will incorporate data from a series of extreme events throughout the country that have occurred since 2018.

In order to verify rainfall assumptions made in the PKE report, HIRDSv4 data was checked for five sites in the Upper part of the Kerikeri and Puketotara catchments shown in figure 1.

Figure 1: Rainfall gauge sites (not all operational) in the Upper Kerikeri catchment



[1] High Intensity Rainfall Design System (NIWA): https://niwa.co.nz/climate-and-weather/high-intensity-rainfall-design-system-hirds

Table 1: HIRDS v4 rainfall depths

Site	Site Ref	Historical data, 1% AEP, 24h	Historical data, 1% AEP 48h	2081-2100 RCP 4.5, 1% AEP, 24h	2081-2100 RCP 4.5, 1% AEP, 48h	2081-2100 RCP 8.5, 1% AEP, 24h	2081-2100 RCP 8.5, 1% AEP, 48h
Puketi[2]	A53282	380mm	487mm	420mm	531mm	464mm	581mm
Taus falls	A53281	343mm	438mm	379mm	477mm	419mm	522mm
Black poll	532811	324mm	407mm	358mm	443mm	396mm	485mm
Tyrees ford	532821	312mm	386mm	344mm	421mm	381mm	461mm
Kerikeri aerodrome aws	A53295	317mm	385mm	349mm	420mm	387mm	459mm

HIRDSv4 provides rainfall depths for a range of AEP from 0.63% (1.58y ARI) to 0.4% (250y ARI), durations up to 120 hours, and future rainfall projections for several time frames and climate scenarios RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. Across the catchment, HIRDSv4 rainfall depths increase with elevation from East to West. The HIRDS v4 data for the above sites is provided in Appendix A.

Whilst there are no national standards for flood scheme design that set design life and climate scenario to plan for, the National Adaptation Plan[3] promotes the consideration of both RCP 4.5 and RCP 8.5 climate scenarios for planning purposes. The MfE Coastal Hazards and Climate Change guidance (2024) recommends the RCP 8.5 scenario is used for assessing sea level rise for land use planning[4].

A number of Councils now extrapolate temperature data to estimate storm rainfall and flood risk beyond 2081-2100 but HIRDSv4 does not provide rainfall estimates beyond this time frame. A reasonably conservative approach would be to adopt 2081-2100 rainfall depths for RCP 8.5, which are approximately 10% - 30% higher than the 350mm figure used in the PKE report. For the purpose of design flow volume assessment, 400mm rainfall over 24 hours (Table 1 for 24h rainfall depths, 2081-2100) has been compared with model flow volumes in the next section of this report.

The design storms used with the Kerikeri catchment flood model are based on 12 hour nested storms and HIRDSv3 rainfall depths which are typically in the range 235mm – 275mm for the upper catchment (with Aerial Reduction Factor of 0.93 applied). As can be seen in Appendix 1, HIRDS v4 rainfall depths (RCP 8.5 in 2081-2100) for the 12 hour duration are in the range 300mm – 350mm, which is significantly higher than the v3 rainfall depths applied to the catchment flood model.

Given the time frames associated with progressing the Kerikeri flood scheme, it is likely that NIWA will release HIRDS v5 prior to completion of investigations, and this will provide an opportunity to review and update design rainfall inputs to the flood model.

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[2] Note the Puketi site is a short distance outside the catchment boundary.
[3] MfE 2022: https://environment.govt.nz/publications/aotearoa-new-zealands-first-national-adaptation-plan/
[4] MfE 2024, Table 8: https://environment.govt.nz/publications/coastal-hazards-and-climate-change-guidance/

3. Catchment Flow Volumes

Catchment flow volumes have been assessed in section 2.2 – 'Catchment Data' of the PKE report. The assessment has assumed a runoff coefficient (RC) of 0.8 (Runoff/Rainfall Volume), which is reasonable for this catchment and reasonably consistent with the RC value reported for the catchment model of 0.77[5].

Table 2: Catchment flow volumes

Designated Catchment	Catchment areas (km2)	Total Flow Volume Generated PKE Report (Million m3)	Flow Volume check 350mm rainfall and RC 0.8	Flow Volume 400mm rainfall and RC 0.8	%
A (Kerikeri River)	41.76	11.692	11.693	13.363	34.5%
B (Puketotara Stream)	28.13	7.876	7.876	9.002	23.2%
C (Maungaparerua Stream)	19.37	5.424	5.424	6.198	16.0%
D (Whiriwhiritoa Stream)	1.54	0.432	0.431	0.493	1.3%
E (Waiwhakangarongaro)	13.99	3.917	3.917	4.477	11.6%
F (Lower Puketotara)	8.54	2.391	2.391	2.733	7.1%
G (Mid-Kerikeri SH10 to confluence)	4.53	1.268	1.268	1.450	3.7%
H (Lower Kerikeri)	3.23	0.9043	0.904	1.034	2.7%
Total Catchment Area (km2)	121.09	Total Volume (Mm3)	33.91	38.75	100.0%
Catchment Area to SH10 (km2)	**103.25**	**Total Volume A+B+C+E (Mm3)**	**28.91**	**33.04**	**85.3%**

Section 2.4 of the PKE report includes a description of the basin area, including maximum expected surface area of 150 Ha at flood RL 80m, and total live storage volume of 10.4 Million m^3. There is no explanation or calculations for how this storage volume has been derived to attenuate the flows as reported. The 10.4M m^3 storage appears to be derived from interpolation of lake surface areas between RL 72m (110Ha) and RL 80m (150Ha), and by multiplying average lake area of 130Ha by 8m of live storage depth.

Calculation of storage volume required to attenuate the 1% AEP+CC[6] event requires a number of additional steps:

Catchment A: Lake inflow hydrograph from Kerikeri River would need to be computed based on a bifurcation rating representing the expected splitting of flows between the lake and the Kerikeri River.

Catchment B: Lake inflow hydrograph from Puketotara Stream and its tributary (catchment E) would need to be computed based on a bifurcation rating representing the expected splitting of flows between the lake and the Puketotara Stream.

Catchment C: This is more straightforward, as 100% of flow from this catchment is routed through the lake. This also includes rainfall within the area of the lake. Total inflow volume estimated is 6.2 Million m^3 for 400mm rainfall depth.

[5] Peer Review Reply - GHD Kerikeri River Catchment Flood Model Upgrade Report Apr 2009
[6] 1% AEP + CC event is the 1% Annual Exceedance Probability event, adjusted for climate change

Lake outflows: Lake outflows need to be computed based on a flow rating for the service spillway under the SH10. Discharge will increase as lake level rises up to the maximum 200 m^3/s capacity of the outlet.

The total flow volume from catchments West of SH10, as reported, is 28.9 Million m^3, so the proposed detention volume of 10.4 Million m^3 represents approximately 36% of this figure (assuming 350mm design rainfall/ 24hr), or 31.5% (400mm design rainfall/ 24 hr). The excess flow volume would need to either by-pass the lake via existing river channels or discharge from the lake outlet through the proposed box culverts.

Peak flows from Upper catchment watercourses in the latest version of the Kerikeri Catchment Model (v040619) 1% AEP + CC are presented below. It should be noted that the rainfall data used to generate these peak flows is from HIRDSv3, and flows using HIRDS v4 are likely to be higher. Additionally, the 12 hr design storms used for the Kerikeri Flood Model will generate lower flow volumes than if 24hr or 48hr storms were used.

Table 3: Catchment Flow Volumes – Kerikeri Flood Model 12 hour storm

Catchment	Model chainage	Peak flow (1% AEP + CC)	Model flow volume (Million m^3)	Catchment area (km^2)	Model flow volume per km^2 (m3)
A – Kerikeri River	4,120m	255 m^3/s	6.11	41.76	146,426
B – Puketotara Stream	3,715m	272 m^3/s	5.77	28.13	205,069
C – Maungaparerua Stream	12,294m	250 m^3/s	3.55	19.37	183,095
E – Waiwhakangarongaro / Whiringatau Stream	4,856m / 521m	117 m^3/s +33m^3/s	2.44	13.99	174,773
TOTAL		927 m^3/s	17.87	103.25	173,075

The model flow volumes from a 12 hour storm for catchments draining to the SH10 is 17.9 Million m^3, which is 62% of the flow volume calculated in the PKE report for a 24 hour storm. Table 3 also shows some disparities in modelled flow volume per km^2 between sub-catchments, in particular a low overall flow volume for the Kerikeri River (catchment A). River flows from the larger catchments at the end of the model run were still relatively elevated (17.3 m^3/s for Kerikeri River and 12.8m^3/s for Puketotara Stream), but this cannot explain the modelled volume differences. A limitation in calibrating model flow volumes is the lack of flow gauges in the upper catchment, limited to just one site on the West side of the SH10 (Tyrees Ford on the Maungaparerua Stream).

The sum of peak flows for catchments upstream of the SH10 is 927 m^3/s which is lower than the model peak flow of 970 m^3/s in the Kerikeri River downstream of the confluence of the Puketotara Stream**.** Whilst there is significant overflow in the model from the Kerikeri River to the Waipapa Stream downstream of the SH10, there are also inflows from sub-catchments to the East of the SH10.

Estimation of Lake Waipapa Inflow Volume and By-pass flows.

Proposed by-pass flows are up to 200m^3 in both the Kerikeri River and Puketotara Stream. Combined peak by-pass flow would be 400m^3/s which equates to 1.44 Million m^3/hr.

Lake Waipapa Inflows / Outflow volumes in Table 4 below have been estimated using the following assumptions:

- For catchment A (Kerikeri River), model flows have been scaled up 25% so that flow volume /km^2 is similar to that in the gauged Maungaperua catchment.
- The model outputs for the 12 hour storm have been scaled up to 24 hours, effectively doubling runoff volume.
- All flows < 200m3/s in the Kerikeri River and Puketotara Stream are assumed to by-pass Lake Waipapa. This does not represent any actual bifurcation rating, and in practice flow diversion will need to commence well below 200m^3/s in both of these channels in order to limit bypass flows to 200m3/s.
- Flows in excess of 200m3/s in the Kerikeri River and Puketotara Stream are assumed to enter Lake Waipapa.
- Lake Waipapa discharge is assumed to increase linearly from 11:00hrs (0m^3/s) to 23:00hrs (200 m^3/s). As shown in figure 2 below, peak inflows to the lake occur at approximately 19:00hrs for the 24 hour storm. Lake levels would continue to rise during the period of peak inflows and until peak inflows reduced below 200m^3/s (at 22:50hrs in the 24 hour storm).

Table 4: Catchment Flow Volumes – Kerikeri Flood Model

Catchment	**Flow Volume Million m^3 (Table 2, 24hr, 400mm rainfall)**	**Peak flow 1% AEP + CC (Model)**	**Model flow Volume by catchment scaled up for 24hr Storm (Million m3)**	**Estimated inflow/outflow to Lake Waipapa 24hr Storm (flow volumes in excess of by-pass flow)**	**Estimated By-pass flow volume (Million m3)**
A – Kerikeri River (upstream of Industrial estate)	13.4	318 m^3/s (scaled up 25%)	15.3	1,876,832m^3 (bypass flow is 200m3/s)	13.4
B/E – Puketotara Stream at SH10 (combined catchments B and E)	13.5	416 m^3/s	16.4	3,734,596m^3 (bypass flow is 200m3/s)	12.7
C – Maungaparerua Stream	6.2	250 m^3/s	7.1	7,093,118m^3 (zero bypass flow)	No by-pass flow
Lake Waipapa Outflow				-4,320,492m^3	4.3
TOTALS	33.1	984 m^3/s	38.8	**Net = 8,384,054m^3**	30.4

Total estimated inflow volume from catchments A, B, C and E is 12.7 Million m^3 for the 24hr event. The estimated lake outflow during this event is approximately 4.3 Million m^3 over 12 hours (up to peak lake level). Approximately 8.4M m^3 of attenuated flood water remains in the lake at the time peak inflows drop below 200m^3/s (refer Figures 2 and 3 below).

Figure 2: Lake Waipapa Inflow hydrographs scaled up for 24hr storm event

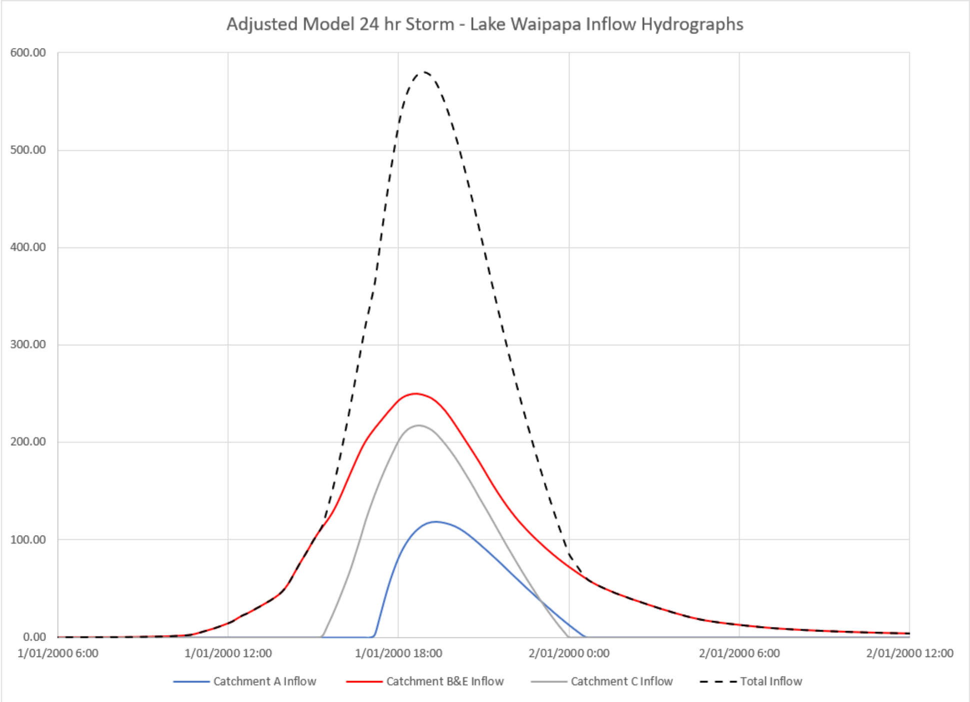
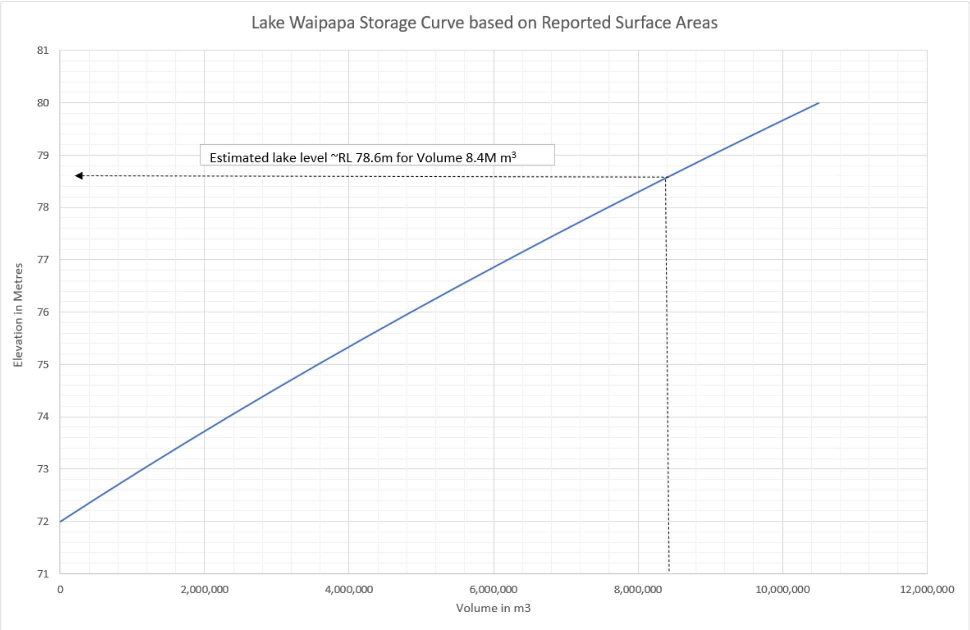


Figure 3: Lake Waipapa Storage Curve and Estimated Volume Utilised at Peak Lake Level



The storage curve above has been estimated using the approximate lake surface areas for RL 72m and RL 80m provided in the PKE report, and assuming that surface area increases linearly with elevation. Lake surface area at RL 80m has been checked using the NRC natural hazards portal area measurement tool and appears to be close to 150 Ha.

The estimates above indicate that the design 1%AEP + CC event can be attenuated as proposed by diverting flows into Lake Waipapa. The flood detention provided would limit peak flow in each of the river channels to 200m^3/s at the SH10, with additional discharge from the lake of up to 200m^3/s occurring approximately 3 hours after flood peaks in the main channels. The estimated utilised flood storage volume, allowing for inflows and outflow is 8.4 Million m^3/s.

There is still significant uncertainty with catchment flow volumes, particularly for catchment A (Kerikeri River). Model flow volumes for this catchment have been scaled up by 25% and then doubled for the 24 hour event. Even with these adjustments, estimated inflows are still substantially lower than for catchment C, which has a similar catchment area.

No bifurcation ratings were assessed for this analysis and it is expected that earlier diversion of flow from the two main river channels would add to lake inflow volumes. In the absence of bifurcation ratings, relatively conservative assumptions have been made for the assessment of river flow volumes.

Given the proposed Lake Waipapa storage volume is substantial, it is envisaged that if inflows increased above those presented above, adjustments could be made to bypass flows (eg. increase above 200m^3/s) and/or outlet capacity to optimise use of the available estimated 10.4 Million m^3 of storage. Alternatively, as discussed in the next sections it is likely additional storage would be required to provide head for routing flows in over-design events.

4. Dam Safety and Over-design events

The Building (Dam Safety) Regulations 2022 came into effect on 13 May 2024. They aim to protect people, property and the environment from potential damage caused by a dam failure. Dams are now classifiable if they are four or more metres in height and store 20,000 or more cubic metres of water or other fluid. The regulations seek to ensure that classifiable dams are well operated and maintained, and regularly monitored.

The Potential Impact Classification (PIC) must be established for all classifiable dams. The impact categories are classified as low, medium or high risk based on an assessment of downstream impacts in case the dam fails. This classification assesses the impact the dam could have on: The community, historical or cultural places, critical or major infrastructure, and the natural environment. This information needs to be included on a Dam Classification Certificate form, and certified by a recognised dam safety engineer.

A framework for the PIC assessment is provided in Schedule 2 of the Building (Dam Safety) Regulations (2022) and the criteria for catastrophic and major damage categories is included in Appendix 2 of this report, together with a table showing how PIC is determined from the damage category. Generally for large classifiable dams, breach scenario modelling will be required to assess population at risk (PAR) and damage category (for consequences over and above the pre-breach condition).

The 1% AEP event is not considered suitable for dam design, particularly high PIC dams. Under s153A of the Building Act – 'Meaning of earthquake-prone dam and flood-prone dam' flood prone dams include high PIC dams that are likely to fail in a flood threshold event.

153A Meaning of earthquake-prone dam and flood-prone dam

(1) A dam is an earthquake-prone dam for the purposes of this Act if the dam—
 (a) is a high potential impact dam or a medium potential impact dam; and
 (b) is likely to fail in an earthquake threshold event (as defined in the regulations).

(2) A dam is a flood-prone dam for the purposes of this Act if the dam—
 (a) is a high potential impact dam or a medium potential impact dam; and
 (b) is likely to fail in a flood threshold event (as defined in the regulations).

Section 153A: inserted, on 15 March 2008, by section 32 of the Building Amendment Act 2008 (2008 No 4).

Section 19 of the Building (Dam Safety) Regulations 2022 defines a flood threshold event as follows:

flood threshold event means,—

(a) in relation to a high potential impact dam, a flood that would result in water or other fluid flowing, into the reservoir formed by the dam, at a flow rate with an AEP of 1 in 500; and

(b) in relation to a medium potential impact dam, a flood that would result in water or other fluid flowing, into the reservoir formed by the dam, at a flow rate with an AEP of 1 in 250.

For the Blue Print One proposal, the dam certification process would need to consider the likely downstream impact associated with the uncontrolled release of 10.4M – 14.4M m^3 of stored water (potentially including dead storage volume). Based on the criteria in Schedule 2, it is anticipated that the damage category would be either high or catastrophic, and the dam would be classified as high PIC. A high PIC dam is considered as a flood prone dam if it is assessed as likely to fail in a 0.2% AEP (1 in 500y) event.

The use of such a long bund for retaining Lake Waipapa potentially increases the risk profile of Blue Print One, as the bund only needs to fail in one location to result in significant downstream impacts.

The NZSOLD Guidelines recommend a Maximum Design Flood (MDF) of between a 0.01% AEP event (1 in 10,000yr ARI) and a PMF (Probable Maximum Flood) for a high PIC dam[7]. The guidelines also state that it is usual to select the PMF as the MDF if potential loss of life exceeds 10 fatalities due to failure of the dam.

NRC followed NZSOLD and ANCOLD guidelines for the design of the Kotuku Detention dam in Maunu, Whangarei. On the recommendation of Riley consultants, the PMF was used as the design event for the emergency spillway sizing, assuming full blockage of the service spillway[8]. Recommended design criteria for the Koutuku dam are outlined below:

[7] NZSOLD – New Zealand Dam Safety Guidelines 2023 - Table 1: Recommended Performance Criteria for Low, Medium and High PIC Dams and Table 4.1: Recommended Minimum Inflow Design Floods

[8] Riley Consultants (2012) – Kotuku Detention Dam: Preliminary Design Report and Hydraulic Optimisation.

Table 3: Recommended design criteria – Koutuku detention dam

Kotuku Detention Dam – Preliminary Design Report
RILEY Ref: 11261/1-A *Page 5*

Table 1: Recommended design criteria

Loading Event	Criteria	Discussed Further in Section
Flooding		
Service Spillway	1% AEP (plus climate change) event to be passed without the emergency spillway operating.	5.1
Emergency Spillway	Maximum Design Flood (MDF) (10,000 year event to Probable Maximum Flood (PMF)) to be passed without dam overtopping (freeboard 0 to 500mm)	5.9
Construction Diversion	20% AEP event to be passed without the cofferdam overtopping.	8.4.6
Earthquakes		
Operating Basis (OBE)	Only minor damage in 150 year event (no yield)	8.4.3
Maximum Design (MDE)	Repairable damage in 2,500 to 10,000 year event	8.4.3

Further consideration will need to be given to the routing of over-design event flows (likely PMF flows) for the Blue Print One proposal. Emergency spillway/s will need to be designed to ensure that the proposed bund is not over-topped in a PMF event to minimise the risk of a breach scenario. Service spillway blockage assumptions are likely to be different to those made for the Kotuku dam, due to the much larger 200m^3/s proposed capacity of the Lake Waipapa outfall. The Koutuku dam service spillway comprises a 1.8m diameter pipe culvert fitted with an outlet throttle plate, so is at higher risk of blockage.

If Lake Waipapa detention volume is designed for a 1% AEP event (with climate allowance) it is possible that for the PMF event the Blue Print One proposal may result in increased PMF flows in the Kerikeri River catchment than would be the case currently. This may arise due to:

- Increased PMF flow transfers from the Puketotara Stream to Lake Waipapa via the proposed spillway.
- Bunding on the left bank of the Kerikeri River at the Waipapa Industrial estate would prevent overflow to the Whiriwhiritoa Stream, thereby retaining more flow in the Kerikeri River downstream

In a PMF event it is possible the diversion spillways would convey a larger proportion of the flow than the main river channels, and the resulting inflows to Lake Waipapa may exceed the capacity of the single outlet. Whilst a single large capacity emergency spillway could be designed for PMF flows, multiple spillways may be required to distribute the flow and avoid excessive concentration of PMF discharge from the lake.

The modelling scope for the new Kerikeri catchment flood model includes simulation of the PMF event. The results can be used during further investigations to assess PMF flow routing for Lake Waipapa, and for comparison of scheme flows and flood extents with the existing PMF baseline.

4.1 Over-design Events

Consideration of previous over-design events is useful to give context to the above discussion.

The independent review[9] of Cyclone Gabrielle flooding in Hawkes Bay has provided some insight into the rainfall intensities, flows and damage experienced by that region in early 2023. This review has also followed in the wake of other reviews done in recent years which have considered catastrophic flood events, including the April 2017 Edgecumbe flood, the July 2021 Westport flood and the January 2023 Auckland flood response. In time, these reviews can be expected to inform national level policy and guidance on flood scheme design and flood management generally.

Hawkes Bay flood February 2023:

The Hawkes Bay flood generated the largest flood flows on record for many of the region's rivers leading to extensive, widespread inundation. The immense flood flows resulted in deaths and widespread destruction and devastation across the region, with financial losses in excess of $5 billion. There was a reported 5.3 kilometres (km) of stopbanks breached, power outages affecting 75,000 people, six major road bridges and a rail bridge washed away and significant damage to the wider roading and rail network, pump stations and wastewater treatment plants. Residential and other buildings were also affected significantly, with almost 1,700 properties flood affected, of which 326 properties are currently classified as Category 3 under the government's land categorisation framework, meaning that the use of these properties for residential purposes was assessed to have an intolerable risk to life from future flood events.

The independent review includes 47 recommendations across 7 different subject areas, including: Structural works (flood protection), flood event management, planning controls and river channel maintenance. A number of the structural works recommendations are relevant to the Blue Print One proposal and excerpts from several of these are provided below:

Recommendation 2: HBRC should ensure that the residual risks associated with floods that exceed the design capacity of stopbank systems are identified, assessed and actively managed. This could be through a combination of planning controls, changes to stopbank systems (e.g. spillways) and event management (e.g. proactive evacuations).

Recommendation 3: When designing new flood management works or improvements to existing systems, HBRC should consider the evolving best practice of "Making Room for the River" in terms of lateral erosion and floodwaters. In addition, these solutions should have known performance in super design events that enables effective event management including precautionary evacuations where appropriate.

Recommendation 5: HBRC should determine the design standard of improved flood management systems based on robust economic analysis to determine the minimum net cost accounting for the investment required for the flood mitigation works and the value of flood damages avoided due to those works. The widely applied 100-year, including climate change, should be considered the minimum standard and not the default standard.

Recommendation 6: When designing flood management works or assessing the adequacy of existing works, HBRC should include historic floods that have not been measured as part of the systematic record in the analysis. For example, the inclusion of the 1938 flood flow estimate for the Esk Valley significantly affects the assigned frequency of the 2023 event.

Commentary and figures on rainfall and flood flows during Cyclone Gabrielle is provided in Appendix 3. A maximum rainfall depth of 546mm was measured in the Esk valley at

[9] Report of the Hawkes Bay Independent Flood Review, July 2024.

Glengarry, of which approximately 400mm fell in 12 hours at a maximum intensity of 56mm/hour. Flow frequency analysis for a number of catchments was updated following the event with the 2023 event ARIs at least halved at a number of sites following inclusion of the 2023 event in the dataset. Flows were estimated from post flood survey as most flow recorders were destroyed during the event.

Kerikeri Flood March 1981

The Kerikeri flood on 19-20 March 1981 resulted from a large cumulonimbus (thunderstorm cloud) centred over the Pungaere catchment. Reporting on this event was undertaken by MWD in 1981, and NIWA in 2009.

Rainfall and flow data for this event is provided in Appendix 3. The event was localised over several catchments, but it appears that high intensity rainfall initiated in the Kapiro area around 17:30, and gradually extended outwards to also impact the Kerikeri catchment (inferred from delayed start to high intensity rainfall at Black Poll gauge). The maximum rainfall intensity recorded was at least 70mm/h (Hunt, 21:30-24:00), and total rain recorded was 448+mm over 9 hours. Given that rain gauges overflowed multiple times, it is conceivable that actual rainfall depth at the centre of the storm exceeded 500mm (Refer Appendix 3 – Figure: Kerikeri 1981 storm rainfall records).

From the Isohyet map, rainfall within the Kerikeri catchment appears to have been in the range 200mm – 400mm with the highest rainfall occurring over the northern part of the catchment. The rainfall intensities, and depth duration over 10 hours for this 1981 event are comparable with those recorded in the Esk Valley in February 2023.

As with the Cyclone Gabrielle event, flow recorders within the Kerikeri and Waipapa catchments were destroyed, but the MWD report includes Slope Area estimates of 1981 flood flows for the Pungaere, Waipapa, Waiwhakangarongaro and Puketotara Streams based on surveyed debris lines.

The upper catchments of the Puketotara Stream and Kerikeri River have only one stream gauge site at Tyrees Ford. This site is located within the Maungaparerua catchment and has a catchment area of 11.1 km^2 (57% of Catchment C area given in the PKE report). This catchment is particularly relevant to the Blue Print One proposal, as 100% of catchment C flow is routed through Lake Waipapa.

MWD estimated a 1981 event peak flow of 225 m^3/s at the Tyrees Ford site based on a surveyed stage height of 4.23m. A lower peak flow and flood level for this site was subsequently estimated by NIWA (2009), using assumed rainfall intensity and rainfall depth for the catchment.

The flow rating from the DHI model aligns closely with the MWD rating, and figures included in Appendix 3 include a flow estimate of 274 m^3/s at Tyrees Ford for the 1981 event, based on an extrapolation of the model rating for this site. The surveyed flood level is approximately 500mm higher than the model Q100+CC event, and the corresponding flow difference is 78m^3/s. It is possible that the model does not effectively replicate the drowning out of the weir structure, and this should be considered further in the current model upgrade.

Appendix 3 also includes a flow frequency analysis table produced in 2014 with updated present day 1% AEP flow of 162m^3/s. The 1981 flow was included in this analysis and has an estimated return period of 340 years. The analysis should ideally be updated with flow data since 2014 to increase confidence in the design flow estimates.

Whilst the information provided in this section does not assist in understanding likely flow volumes for the 1981 event (as flow gauges were destroyed), it is clear that peak flows were well in excess of the model 1% AEP + CC flows, and this underscores the importance of designing a future flood detention scheme to be resilient to over-design events.

5. Alternative Spillway Configurations

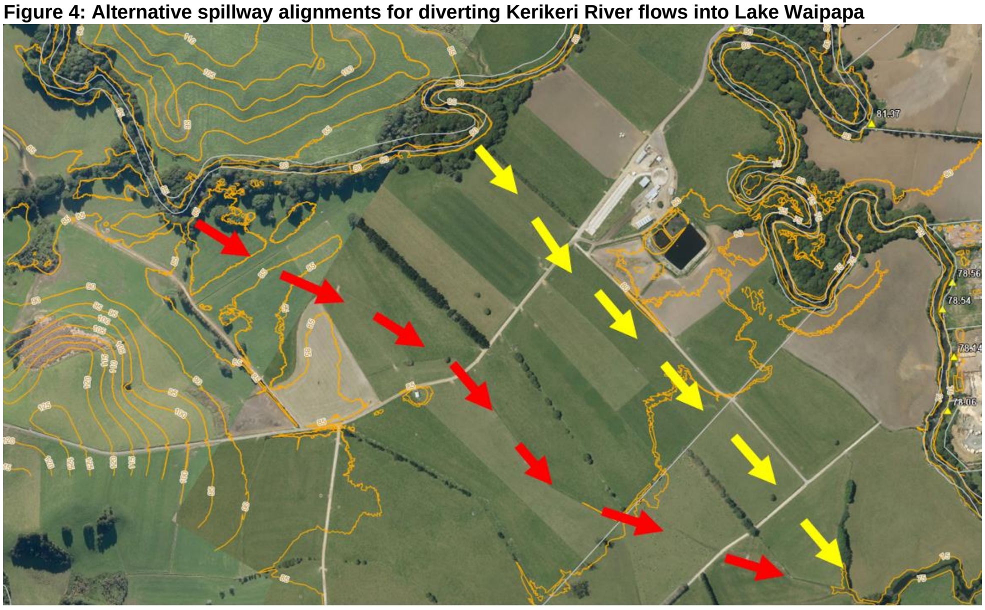
This section considers the proposed locations for flow transfers from the Kerikeri River and Puketotara Stream into Lake Waipapa. The proposed control weirs and diversion channels are shown on the Site Plan A3/BP1-S3 in the PKE report. It is anticipated that these diversions would be passively controlled to minimise operation & maintenance requirements, as well as potential liability that arises from actively controlled flood schemes.

5.1 Kerikeri River Diversion

For the Kerikeri River the control weir is located in the vicinity of vegetated river loops to the West of the Waipapa Industrial Estate. Forming a control structure in this area is likely to prove challenging, as it will require significant removal of vegetation and the hydraulics of the channel are complicated due to the river loops. River bank scour will need to be addressed in this area to reduce risk of diversion structures being undermined. The PKE plan also shows a bund on the true left bank of the Kerikeri River in the vicinity of the river loops which is required to prevent overflow into the Whiriwhiritoa Stream catchment.

Diverting Kerikeri River flows to Lake Waipapa further upstream would either remove or reduce the need for bunding on the true left bank adjacent to the industrial estate. The alternative spillway locations shown in figure 4 divert flows from the river where there are fewer meanders to complicate design of the flow bifurcation and the river channel appears to be more stable in this area.

Figure 4: Alternative spillway alignments for diverting Kerikeri River flows into Lake Waipapa



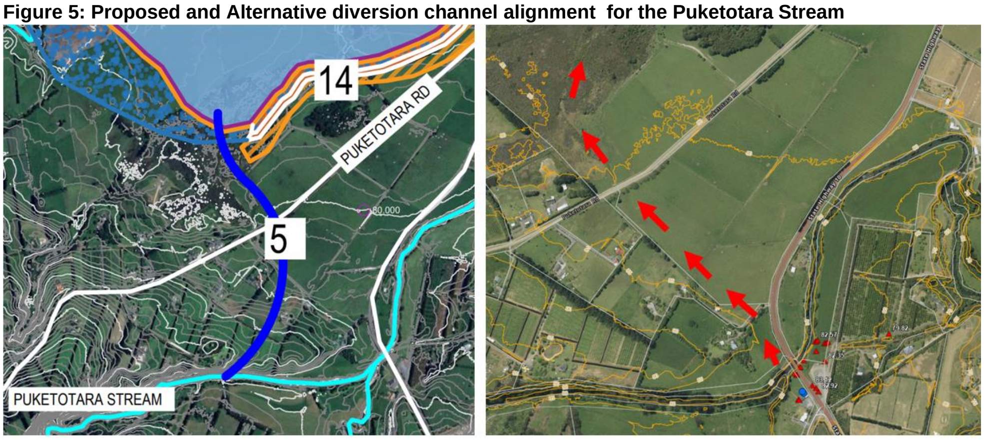
The construction of a high bund on the true right bank of the Kerikeri River adjacent to the industrial estate would transfer any channel overflow to the left bank, into the Industrial Estate. It is possible that risk of this is low for the design event, due to upstream diversion, however the bund may exacerbate flooding of the Industrial Estate for a PMF event. Removal of the section of the bund on the true left bank would reduce the risk to the industrial estate in a PMF event, as overflows would occur as they do currently, across farm land and into the Whiriwhiritoa Stream.

5.2 Puketotara Stream Diversion

The location of the Puketotara Stream diversion is proposed in the report to be upstream of the confluence with the Waiwhakarongaro Stream. The diversion channel as shown would require a 10-15m deep excavation through the ridge that runs along the North side of the Puketotara stream. Locating the intake to this diversion channel further downstream would have several benefits including: reduced earthworks cost and environmental footprint, reduced impact on private property, and more certainty in terms of regulating lake by-pass flows as it is downstream of the confluence with the Waiwhakarongaro Stream. There is one access drive to several private properties which would either require a spillway crossing, or the accessway could be realigned to connect to the Puketotara Road.

The ground level at the proposed intake immediately upstream of the SH10 is RL 83m – RL 84m. If the invert level of the intake was below RL 80m (eg. RL 78m-79m), this would potentially allow the channel to back flow when lake levels were high. However this may also result in excessive diversion unless a weir structure was put in place with flap gates or some other mechanism to regulate flow direction.

Figure 5: Proposed and Alternative diversion channel alignment for the Puketotara Stream



6. Further considerations

If the Blue Print One proposal progresses to the design and consenting stage, further consideration will need to be given to the water quality aspects associated with such a large water body, and sediment transport through the lake. Within Northland, water quality issues have arisen with large shallow lakes such as Lake Omapere which has been prone to blooms of toxic algae. Over time the intended 4m depth would likely be reduced due to sediment inflows.

Further assessment is needed of the sediment volumes that would be transported into the lake from Kerikeri River and Puketotara Stream flood inflows. Additionally, 100% of Maungaparerua Stream sediment and bed load would be transported into the lake. The formation of the lake would result in the loss of lower part of the Maungaparerua Stream and over time it is likely that alluvial deposits from this stream would build up as flows entered the lake, forming a delta in the area of the proposed floating solar farm shown in figure A3/BP1-S3 of the PKE report. If the lake were to be used for recreation and / or water supply, removal of this sediment would be problematic. The PKE report refers to pre-treatment of inflows and one option would be to excavate gravel traps at upstream sites on the Maungaparerua stream to reduce the volume of sediment and gravels entering the lake. It would be challenging, potentially impossible, to significantly reduce flood sediment loads carried by the larger river inflows.

The maximum lake level of RL 80m is above most of the Industrial Estate and the bund on the true right bank of the Kerikeri River would be required to prevent outflow from the lake. It is possible that if the bund along this section were to fail when river levels were high, breach flows could conceivably traverse the river channel and flow into the estate.

Seepage of lake flows under the bund would need to be prevented due to potential for piping failures. Given the proposed lake area is a large flood plain there is likely to be a significant depth of alluvial deposits which would need to be excavated to form a competent foundation for the bund. Depending on the depth of the alluvium, the cost may be prohibitive and the environmental effects and residual risk may be deemed excessive at consenting stage.

The cost of the proposed scheme would be substantial, due to the volume of the earthworks required, the weirs, diversion channels and lake outfall. Large box culverts or bridges would be required under the SH10 as well as under Puketotara Road. Land acquisition costs, including creation of a 40m wide buffer strip along all the watercourses, and consenting costs would be substantial for such a proposal.

The benefits suggested in the report would need to assessed carefully. Whilst there is potential for hydro power and a large recreational area, the ability of the proposed scheme to enable development of 3,000 additional dwellings appears questionable. In practice only limited areas of catchments F and H are within the mapped flood plain East of the SH 10, as the channels downstream of Kerikeri Falls and Double Falls are deeply incised. The sub-catchment which would benefit most from the scheme is sub-catchment G (Waitotara Drive/ Waipapa Road/ Rainbow Falls Road and 1878 SH10) but much of this sub-catchment on the true left bank has already been developed.

Flood risk reduction to sub-catchment G could be delivered in other ways. The NRC investigated a spillway flood scheme a decade ago but this was not progressed due to potential downstream effects of the diversion. There was excessive uncertainty associated with the extent to which the spillway scheme would have increased flows within the lower river, resulting from the reduction of overflow across Waipapa Road. Further monitoring and analysis to increase confidence in the assessment of catchment overflows was recommended at that time.

Other alternatives previously considered include river channel benching on the Kerikeri River at the dog leg bend where it passes close to Waipapa Road. This could potentially increase channel capacity to 300m^3/s and allow for higher by-pass flows around Lake Waipapa. The effect on flows in the lower Kerikeri River resulting from preventing overflows to the Waipapa Stream catchment would likely be offset by the attenuation provided by Lake Waipapa.

Upstream detention at sites such as K3A on the Kerikeri River provide another, likely lower cost option to reduce flood risk to catchment G and downstream. An upstream reservoir at this location could potentially provide a multi-purpose function as proposed for the Blue Print One scheme but with a lower risk profile.

Flooding from the Puketotara Stream downstream of Double Falls has not been a significant issue historically. If attenuation of only Kerikeri River flows was undertaken, then flood risk in the lower river downstream of the confluence would still be reduced. The breakout flows from the Puketotara Stream in the vicinity of the SH 10 could be reduced or prevented by increasing the capacity of the spillway on the right bank that diverts flood flow immediately downstream of the SH10 bridge. The removal of the old hydro-electric water take weir located on the main channel between SH10 and Double falls would potentially increase channel capacity along this reach, thus reducing overflow to the Kerikeri River catchment.

7. Conclusions

Whilst the Blue Print One proposal is still at early concept stage, this review has established that the storage volume of 10.4 Million m^3 identified for Lake Waipapa is likely to be sufficient to attenuate the 1% AEP + CC flood flows as proposed. The assessed volume required for attenuation of the 1% AEP event is 8.4 Million m^3, resulting in an estimated maximum lake level of RL 78.6m.

There is some uncertainty associated with the lake inflows as the catchments upstream of the SH10 are largely ungauged, and this reduces confidence in model flow volumes. In particular, the flow volume and peak flow from the Kerikeri River (catchment A) appear to be under-represented in the model outputs. Additional gauge sites in the upper catchment would be beneficial to support further investigations for the flood scheme.

In this report alternative locations have been suggested for diversion weirs and spillways from the main river channels to Lake Waipapa. A limitation of this review is that bifurcation ratings have not been developed for these flow diversions. For passively controlled diversions from the main river channels, diversion would need to be initiated at flows well below $200m^3/s$ in order to limit by-pass flows to $200m^3/s$ in each channel. Use of bifurcation ratings would increase inflows to Lake Waipapa but assessment of this requires further work to develop site specific bifurcation ratings for the two diversion intakes. For this reason, a relatively conservative approach has been taken with flow volume estimates, and the scaling up of river flows for the 24 hour event has resulted in flow volume in excess of that expected from 400mm of rainfall in 24 hours, with a runoff coefficient of 0.8.

Whilst some scaling up of rainfall was undertaken to inform the Blue Print One proposal, the rainfall depth of 350mm considered for the scheme appears to be lower than rainfall depths in HIRDS v4 for the upper catchment. In addition no consideration has been given to over-design event storm rainfall and flows (such as the PMF), and how those flows would be routed through Lake Waipapa without over-topping the bund.

Notwithstanding this, the substantial length of the proposed bund that retains the lake increases its risk exposure, as it would only need to fail at one point in flood conditions to release a large volume of stored water. It is recognised that the depth of alluvium along the proposed alignment of the bund may compromise the viability of the scheme. The resilience of the bund to over-design and seismic events would also need to be considered further at the design stage.

8. Recommendations

The benefits, risks and costs of the Blue Print One proposal should be weighed up against alternative options before progressing to the design stage. Establishing the depth of alluvium along the alignment of the bund should be undertaken to confirm viability.

Recommendations relating to hydrological aspects are provided below:

a) Further assessment is needed for PMF flows, and how these would be routed through, and discharged from the lake. The bund crest level would need to be set with a freeboard above PMF flood levels. PMF flows and flood extents should be assessed with and without the proposed Blue Print One scheme in place so that the implications for future subdivision and land development can be considered.

b) Installation of additional river gauge sites in the upper catchment should be undertaken if a flood scheme is to be progressed as they would add confidence to the assessment of sub-catchment peak flows and flow volumes. The previously established site on the Kerikeri River just downstream of SH10 could be re-established as the flow rating for that site had been confirmed with flood gaugings done by NRC in 2014. Alternatively, a short distance downstream of the K3A site would be a useful gauge site to isolate catchment A flows. An additional site on the Puketotara Stream or Waiwhakangarongaro stream upstream of the confluence would also value, but is a lower priority than Kerikeri River.

c) Upper catchment peak flows and flow volumes from each of the sub-catchments should be critically assessed as part of the development of the new Kerikeri / Waipapa catchment flood model. The flow frequency analysis for Tyrees Ford presented in Appendix 3 should be updated to include flow records collected since 2014. Additionally the hydraulics of the v notch weir for high flow should be reviewed to improve confidence in the 1981 flood flow estimate.

d) The new Kerikeri catchment flood model should be updated with rainfall from HIRDS v4, and should it be made available, rainfall data from HIRDS v5 (under development) should be used to re-assess design flows and flow volumes for a range of storm durations to confirm storage volume requirements.

e) Alternative sites for the diversion weirs on the main river channels have been suggested, and river inflows to Lake Waipapa should be re-assessed in tandem with the development of bifurcation ratings for each of the river intake sites. A flow rating for the outfall from the lake should also be developed to better assess outflow volumes and storage requirements.

f) Further consideration should be given to alternative solutions to Blue Print One. Specifically whether it is beneficial to divert / attenuate flood flows from the Puketotara Stream as proposed. Providing flood detention only for the Kerikeri River and / or Maungaparerua Stream would reduce flood storage requirements yet still provide significant flood risk reduction benefit to sub-catchment G (Waitotara Drive/ Waipapa Road/ Rainbow Falls Road and 1878 SH10) as well as the lower river downstream of the confluence with the Puketotara Stream. Flood overflow from the Puketotara Stream to the Kerikeri catchment could be reduced if needed, by bunding adjacent to the SH10, and/or by increasing spillway capacity on the right bank downstream of the SH10.

Toby Kay, MSc
28/10/2024

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Appendix 1 – HIRDS v4 Rainfall Data

HIRDS V4 Depth-Duration-Frequency Results													
Sitename: PUKETI													
Site ID: A53282													
Coordinate system: NZGD1949													
Longitude: 173.794													
Latitude: -35.213													
DDF Mode	Paramete	c	d	e	f	g	h	i					
	Values:	0.001072	0.591251	0.000528	-0.0065	0.256495	-0.01195	3.321943					
	Example:	Duration (	ARI (yrs)	x	y	Rainfall Depth (mm)							
		24	100	3.178054	4.600149	380.0466							

Rainfall depths (mm) :: Historical Data

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	9.99	14.6	18.4	27.7	41.7	77.1	109	148	189	211	224	233
2	0.5	11	16	20.2	30.4	45.7	84.7	120	163	208	232	247	256
5	0.2	14.2	20.9	26.3	39.6	59.7	111	157	213	272	304	323	336
10	0.1	16.7	24.4	30.9	46.5	70	130	184	250	320	357	380	395
20	0.05	19.2	28.1	35.5	53.4	80.5	150	213	288	369	412	439	456
30	0.033	20.6	30.2	38.2	57.6	86.8	161	229	311	398	445	474	493
40	0.025	21.7	31.8	40.2	60.5	91.3	170	241	328	419	469	499	519
50	0.02	22.5	33	41.7	62.9	94.8	176	251	340	436	487	519	539
60	0.017	23.2	34	42.9	64.7	97.6	182	258	351	449	502	535	556
80	0.013	24.2	35.5	44.9	67.7	102	190	270	367	470	526	560	583
100	0.01	25	36.7	46.4	70	106	197	280	380	487	544	580	603
250	0.004	28.3	41.5	52.6	79.3	120	223	318	432	553	619	660	686

Rainfall depths (mm) :: RCP4.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	11.4	16.7	21.1	31.7	47.3	85.9	120	161	202	224	237	246
2	0.5	12.6	18.4	23.2	34.9	52.2	94.7	132	177	223	247	262	271
5	0.2	16.5	24.1	30.4	45.8	68.5	125	175	233	294	327	346	358
10	0.1	19.3	28.3	35.8	53.8	80.6	147	206	275	347	385	408	423
20	0.05	22.2	32.6	41.2	62	93	170	237	317	401	445	472	488
30	0.033	24	35.1	44.4	66.9	100	183	256	342	433	481	510	528
40	0.025	25.2	36.9	46.7	70.4	106	193	270	361	456	507	537	557
50	0.02	26.2	38.4	48.5	73.1	110	200	281	375	475	527	559	578
60	0.017	26.9	39.5	50	75.3	113	207	290	387	489	544	576	596
80	0.013	28.2	41.4	52.3	78.9	118	216	303	405	513	570	604	626
100	0.01	29.1	42.8	54.1	81.6	122	224	314	420	531	590	626	648
250	0.004	32.9	48.4	61.2	92.4	139	254	356	477	604	671	712	737

Rainfall depths (mm) :: RCP8.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	13.1	19.1	24.1	36.2	53.7	95.8	132	175	217	239	251	260
2	0.5	14.4	21.1	26.6	40	59.5	106	146	193	240	265	279	288
5	0.2	19	27.7	35	52.7	78.6	141	194	256	319	352	371	383
10	0.1	22.3	32.7	41.3	62.2	92.7	166	230	302	378	417	439	453
20	0.05	25.7	37.7	47.6	71.8	107	192	266	349	437	483	509	525
30	0.033	27.7	40.7	51.4	77.5	116	208	287	378	473	522	551	568
40	0.025	29.2	42.8	54.1	81.5	122	219	303	399	498	551	580	599
50	0.02	30.3	44.5	56.2	84.7	127	228	315	414	519	573	604	623
60	0.017	31.2	45.8	57.9	87.3	130	235	325	428	535	592	623	642
80	0.013	32.7	48	60.7	91.5	137	246	340	448	561	620	653	674
100	0.01	33.8	49.6	62.7	94.6	141	255	353	464	581	641	677	698
250	0.004	38.2	56.1	71	107	160	289	400	528	660	730	771	794

HIRDS V4 Depth-Duration-Frequency Results
Sitename: TAUS FALLS
Site ID: A53281
Coordinate system: NZGD1949
Longitude: 173.8155
Latitude: -35.2468

DDF Mode	Paramete	c	d	e	f	g	h	i
	Values:	0.001094	0.566065	-0.01456	-0.00313	0.25735	-0.01215	3.34385
	Example:	Duration (	ARI (yrs)	x	y	Rainfall Depth (mm)		
		24	100	3.178054	4.600149	343.0959		

Rainfall depths (mm) :: Historical Data

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	9.98	15	19	28.3	41.6	73.2	101	134	170	191	206	216
2	0.5	10.9	16.5	20.9	31.1	45.7	80.4	111	147	187	210	226	238
5	0.2	14.2	21.4	27.2	40.5	59.6	105	145	192	245	276	297	312
10	0.1	16.7	25.1	31.9	47.5	69.9	123	170	226	288	324	349	367
20	0.05	19.1	28.9	36.6	54.7	80.5	142	196	261	332	374	403	424
30	0.033	20.6	31.1	39.4	58.9	86.7	153	211	281	358	404	435	458
40	0.025	21.7	32.7	41.5	61.9	91.2	161	222	296	377	425	458	482
50	0.02	22.5	33.9	43	64.3	94.7	167	231	307	392	442	476	501
60	0.017	23.1	34.9	44.3	66.2	97.5	172	238	317	404	455	491	516
80	0.013	24.2	36.5	46.3	69.2	102	180	249	332	423	477	514	541
100	0.01	25	37.7	47.9	71.6	105	187	258	343	438	494	532	560
250	0.004	28.2	42.6	54.1	81	119	212	292	389	497	561	604	636

Rainfall depths (mm) :: RCP4.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	11.4	17.2	21.7	32.4	47.2	81.5	110	145	182	203	217	228
2	0.5	12.6	18.9	23.9	35.7	52.1	89.9	122	160	200	224	240	252
5	0.2	16.5	24.8	31.4	46.8	68.5	118	161	210	265	296	317	332
10	0.1	19.3	29.1	36.9	55.1	80.6	140	190	248	312	350	374	392
20	0.05	22.2	33.5	42.5	63.5	92.9	161	219	286	361	404	433	454
30	0.033	24	36.1	45.8	68.4	100	174	236	309	390	437	468	490
40	0.025	25.2	38	48.2	72	105	183	249	326	411	460	493	517
50	0.02	26.1	39.4	50.1	74.8	110	190	259	339	427	478	513	537
60	0.017	26.9	40.6	51.5	77	113	196	267	349	440	493	529	554
80	0.013	28.2	42.5	53.9	80.6	118	205	279	366	461	517	554	581
100	0.01	29.1	43.9	55.8	83.3	122	213	289	379	477	535	574	601
250	0.004	32.9	49.6	63.1	94.3	138	241	328	430	542	608	652	683

Rainfall depths (mm) :: RCP8.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	13	19.6	24.8	37	53.6	90.9	121	158	195	216	230	241
2	0.5	14.4	21.6	27.4	40.9	59.4	101	135	174	216	240	256	267
5	0.2	19	28.5	36.2	53.9	78.5	134	179	231	287	320	340	355
10	0.1	22.3	33.6	42.6	63.6	92.7	158	212	273	340	379	403	421
20	0.05	25.7	38.8	49.2	73.4	107	183	245	316	394	438	467	487
30	0.033	27.7	41.8	53.1	79.2	116	197	265	341	426	474	506	527
40	0.025	29.2	43.9	55.8	83.3	122	208	279	360	448	500	532	556
50	0.02	30.3	45.7	58	86.7	126	216	290	374	467	519	554	578
60	0.017	31.2	47	59.7	89.2	130	223	299	386	481	536	572	596
80	0.013	32.7	49.3	62.6	93.5	136	234	313	404	505	562	599	626
100	0.01	33.8	50.9	64.7	96.7	141	242	325	419	522	581	621	648
250	0.004	38.1	57.6	73.1	109	160	274	368	476	593	661	706	736

HIRDS V4 Depth-Duration-Frequency Results
Sitename: Maungaparerua at Black Poll
Site ID: 532811
Coordinate system: NZGD1949
Longitude: 173.8599
Latitude: -35.2269

DDF Mode	Paramete	c	d	e	f	g	h	i
	Values:	0.002124	0.518325	-0.00282	-0.00486	0.251112	-0.01135	3.372447
	Example:	Duration (	ARI (yrs)	x	y	Rainfall Depth (mm)		
		24	100	3.178054	4.600149	324.1919		

Rainfall depths (mm) :: Historical Data

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	11.7	16.5	20.3	29.1	41.6	71.1	96.3	126	157	174	184	192
2	0.5	12.8	18.1	22.3	31.9	45.6	78	106	138	172	191	203	211
5	0.2	16.6	23.4	28.9	41.4	59.3	102	138	181	226	250	266	277
10	0.1	19.3	27.3	33.7	48.4	69.4	119	162	212	265	295	313	326
20	0.05	22.1	31.3	38.7	55.6	79.7	137	187	245	306	341	362	377
30	0.033	23.8	33.7	41.6	59.9	85.9	148	202	265	331	368	392	408
40	0.025	25	35.4	43.7	62.9	90.4	156	212	279	349	388	413	430
50	0.02	25.9	36.7	45.4	65.3	93.8	162	221	290	363	403	429	447
60	0.017	26.7	37.8	46.7	67.3	96.7	167	227	299	374	416	443	462
80	0.013	27.9	39.5	48.8	70.4	101	175	238	313	392	437	465	484
100	0.01	28.8	40.9	50.5	72.8	105	181	247	324	407	452	482	502
250	0.004	32.5	46.2	57.1	82.5	119	205	281	370	464	517	551	574

Rainfall depths (mm) :: RCP4.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	13.4	18.9	23.3	33.3	47.2	79.2	106	136	168	184	195	202
2	0.5	14.7	20.8	25.6	36.6	52.1	87.2	117	150	185	204	215	223
5	0.2	19.1	27	33.3	47.8	68.1	115	153	198	244	269	284	295
10	0.1	22.4	31.7	39.1	56.1	80	135	181	233	288	318	336	349
20	0.05	25.7	36.4	44.9	64.5	92.1	156	209	269	333	368	389	404
30	0.033	27.7	39.2	48.4	69.6	99.3	168	225	291	360	398	422	437
40	0.025	29	41.2	50.8	73.1	104	177	238	307	380	420	444	461
50	0.02	30.1	42.7	52.8	76	109	184	247	319	395	437	463	480
60	0.017	31	44	54.3	78.3	112	190	255	329	408	451	477	495
80	0.013	32.5	46	56.9	82	117	199	267	345	428	473	501	520
100	0.01	33.5	47.6	58.8	84.7	121	206	277	358	443	490	520	539
250	0.004	37.9	53.8	66.5	96.1	138	234	315	408	506	560	594	616

Rainfall depths (mm) :: RCP8.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	15.3	21.6	26.6	38.1	53.6	88.3	116	149	180	197	207	214
2	0.5	16.9	23.8	29.3	42	59.4	97.7	129	164	199	218	229	237
5	0.2	22.1	31.2	38.4	55.1	78.1	129	171	217	265	290	305	315
10	0.1	25.9	36.6	45.1	64.8	91.9	152	202	257	313	344	362	374
20	0.05	29.7	42.1	51.9	74.7	106	176	234	297	363	398	420	433
30	0.033	32	45.4	56	80.6	115	191	253	321	394	432	455	470
40	0.025	33.6	47.7	58.8	84.7	120	201	266	339	415	456	480	496
50	0.02	34.9	49.5	61.2	88.1	125	209	277	352	432	474	500	516
60	0.017	36	51	63	90.7	129	216	286	364	446	490	516	533
80	0.013	37.6	53.4	66	95.1	135	226	300	382	468	514	542	560
100	0.01	38.9	55.2	68.2	98.3	140	234	311	396	485	533	562	581
250	0.004	43.9	62.4	77.2	111	159	266	354	452	554	609	643	664

HIRDS V4 Depth-Duration-Frequency Results
Sitename: Maungaparerua at Tyrees Weir
Site ID: 532821
Coordinate system: NZGD1949
Longitude: 173.8838
Latitude: -35.2371

DDF Mode	Paramete	c	d	e	f	g	h	i
	Values:	0.00277	0.557654	-0.00972	-0.00521	0.250772	-0.01155	3.286302
	Example:	Duration (	ARI (yrs)	x	y	Rainfall Depth (mm)		
		24	100	3.178054	4.600149	311.9376		

Rainfall depths (mm) :: Historical Data

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	9.83	14.4	18.1	26.7	39.1	68.3	92.9	121	148	162	170	174
2	0.5	10.7	15.8	19.8	29.3	42.8	74.9	102	133	163	178	187	192
5	0.2	13.9	20.4	25.6	38	55.7	97.7	133	174	213	234	245	253
10	0.1	16.1	23.8	29.9	44.4	65.1	115	157	204	251	275	289	298
20	0.05	18.4	27.2	34.3	50.9	74.8	132	180	236	291	319	335	345
30	0.033	19.8	29.2	36.8	54.7	80.6	142	195	255	314	345	362	373
40	0.025	20.8	30.7	38.7	57.5	84.7	150	205	268	331	363	382	394
50	0.02	21.5	31.8	40.1	59.7	87.9	155	213	279	344	378	398	410
60	0.017	22.1	32.7	41.3	61.4	90.6	160	220	287	355	390	410	423
80	0.013	23.1	34.2	43.1	64.2	94.7	168	230	301	372	409	431	444
100	0.01	23.9	35.3	44.6	66.4	98	174	238	312	386	424	446	460
250	0.004	26.9	39.8	50.3	75.1	111	197	271	356	441	485	511	527

Rainfall depths (mm) :: RCP4.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	11.2	16.5	20.7	30.6	44.4	76.1	102	131	158	172	179	184
2	0.5	12.3	18.1	22.7	33.6	48.9	83.8	112	144	175	190	198	203
5	0.2	16	23.5	29.6	43.8	64	110	148	190	231	251	262	269
10	0.1	18.7	27.5	34.7	51.4	75.1	130	175	224	273	297	310	319
20	0.05	21.4	31.6	39.8	59.1	86.4	150	202	259	316	344	360	369
30	0.033	23	34	42.8	63.6	93.2	162	218	280	342	372	390	400
40	0.025	24.1	35.6	45	66.8	97.9	170	230	295	360	393	411	422
50	0.02	25	37	46.7	69.4	102	177	239	307	375	409	428	440
60	0.017	25.8	38.1	48	71.5	105	182	246	317	387	423	442	454
80	0.013	26.9	39.8	50.2	74.8	110	191	258	332	406	443	464	477
100	0.01	27.8	41.1	51.9	77.3	113	198	267	344	421	459	481	494
250	0.004	31.3	46.4	58.6	87.4	129	225	304	393	481	525	551	566

Rainfall depths (mm) :: RCP8.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	12.8	18.8	23.7	34.9	50.4	84.9	112	142	170	183	190	195
2	0.5	14.1	20.7	26.1	38.5	55.8	93.9	124	157	188	203	211	216
5	0.2	18.4	27.1	34.1	50.5	73.3	124	165	208	250	271	281	288
10	0.1	21.6	31.8	40	59.3	86.3	147	195	247	297	322	334	342
20	0.05	24.8	36.5	46	68.3	99.5	170	226	285	345	373	389	397
30	0.033	26.6	39.3	49.6	73.7	107	183	244	309	373	404	421	430
40	0.025	28	41.3	52.1	77.4	113	193	257	326	393	427	444	455
50	0.02	29	42.9	54.1	80.5	117	201	267	339	410	444	463	473
60	0.017	29.9	44.1	55.7	82.8	121	207	276	350	423	459	478	489
80	0.013	31.2	46.2	58.3	86.8	127	217	289	367	445	482	502	514
100	0.01	32.2	47.7	60.2	89.7	131	225	300	381	461	499	521	533
250	0.004	36.3	53.8	68	101	148	256	342	435	526	571	596	610

HIRDS V4 Depth-Duration-Frequency Results
Sitename: KERIKERI AERODROME AWS
Site ID: A53295
Coordinate system: NZGD1949
Longitude: 173.911
Latitude: -35.262

DDF Mode	Paramete	c	d	e	f	g	h	i
	Values:	0.00163	0.565356	-0.01787	-0.00442	0.256652	-0.01204	3.333236
	Example:	Duration (	ARI (yrs)	x	y	Rainfall Depth (mm)		
		24	100	3.178054	4.600149	316.5266		

Rainfall depths (mm) :: Historical Data

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	9.85	14.8	18.8	28	41	71	95.5	122	148	160	167	172
2	0.5	10.8	16.3	20.6	30.7	45.1	78	105	135	163	177	184	189
5	0.2	14	21.1	26.9	40.1	58.8	102	138	177	214	232	242	248
10	0.1	16.4	24.8	31.4	47	69	120	162	208	252	273	286	293
20	0.05	18.8	28.4	36.1	54	79.4	138	186	240	291	316	330	339
30	0.033	20.3	30.6	38.9	58.2	85.6	149	201	259	314	341	357	366
40	0.025	21.3	32.2	40.9	61.2	90	157	212	272	331	360	376	386
50	0.02	22.1	33.4	42.4	63.5	93.5	163	220	283	344	374	391	401
60	0.017	22.7	34.4	43.7	65.4	96.3	168	227	292	355	386	403	414
80	0.013	23.8	35.9	45.7	68.4	101	176	238	306	372	404	423	434
100	0.01	24.6	37.1	47.2	70.7	104	182	246	317	385	418	438	449
250	0.004	27.7	41.9	53.4	80.1	118	206	279	360	438	477	499	512

Rainfall depths (mm) :: RCP4.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	11.3	17	21.5	32	46.6	79.1	105	133	158	170	177	181
2	0.5	12.4	18.7	23.7	35.3	51.4	87.3	116	146	175	188	196	200
5	0.2	16.2	24.4	31	46.3	67.6	115	153	193	231	249	259	265
10	0.1	19	28.7	36.4	54.4	79.5	136	180	228	273	295	306	313
20	0.05	21.9	33	41.9	62.7	91.7	157	208	263	316	341	355	362
30	0.033	23.6	35.6	45.2	67.6	99	169	225	285	342	369	384	392
40	0.025	24.7	37.4	47.5	71.1	104	178	237	300	360	389	405	414
50	0.02	25.7	38.8	49.4	73.9	108	185	246	312	375	405	421	430
60	0.017	26.5	40	50.8	76.1	111	191	254	322	386	418	434	444
80	0.013	27.7	41.8	53.2	79.7	117	200	266	337	405	438	455	466
100	0.01	28.6	43.2	55	82.4	121	207	276	349	420	453	472	482
250	0.004	32.3	48.8	62.2	93.3	137	235	313	397	478	517	538	550

Rainfall depths (mm) :: RCP8.5 for the period 2081-2100

ARI	AEP	10m	20m	30m	1h	2h	6h	12h	24h	48h	72h	96h	120h
1.58	0.633	12.9	19.4	24.6	36.6	52.9	88.2	115	144	170	182	188	191
2	0.5	14.2	21.4	27.1	40.4	58.7	97.7	128	160	188	202	209	212
5	0.2	18.7	28.1	35.7	53.3	77.5	130	170	212	251	269	278	283
10	0.1	22	33.1	42.1	62.9	91.4	153	201	251	297	319	330	336
20	0.05	25.3	38.2	48.5	72.6	106	178	233	290	345	370	383	389
30	0.033	27.3	41.2	52.4	78.3	114	192	252	314	373	400	415	422
40	0.025	28.7	43.3	55	82.4	120	203	266	332	393	423	437	445
50	0.02	29.8	45	57.2	85.6	125	210	276	345	410	440	455	463
60	0.017	30.7	46.3	58.9	88.2	129	217	285	356	422	454	470	478
80	0.013	32.1	48.5	61.7	92.4	135	227	299	373	444	476	492	502
100	0.01	33.2	50.1	63.8	95.6	139	236	310	387	459	493	511	520
250	0.004	37.4	56.7	72.1	108	158	268	352	440	523	562	582	593

Appendix 2 – NZ Dam Safety Regulation – Dam Classification

Schedule 2
Dam classification

r 9

Table 1—Determination of assessed damage level

Damage level	Community	Cultural	Critical or major infrastructure: *Damage*	Critical or major infrastructure: *Time to restore critical or major infrastructure to normal pre-dam failure operation*[1]	Natural environment
	Specified categories				
Catastrophic	One or more of the following apply: • 50 or more household units rendered uninhabitable: • 20 or more commercial or industrial facilities rendered inoperable: • 2 or more community facilities rendered inoperable or uninhabitable	Irreparable loss to 2 or more historical or cultural sites	Two or more critical or major infrastructure facilities rendered inoperable	One year or more	Extensive and widespread damage, with permanent, irreparable effects on the natural environment
Major	One or more of the following apply: • 4 or more but less than 50 household units rendered uninhabitable: • 5 or more but less than 20 commercial or industrial facilities rendered inoperable: • 1 community facility rendered inoperable or uninhabitable	One or both of the following apply: • irreparable loss to 1 historical or cultural site: • loss to 1 or more historical or cultural sites where it is possible, but impracticable, to fully restore the site	One critical or major infrastructure facility is rendered inoperable	Three months or more but less than 1 year	Extensive and widespread damage where it is possible, but impracticable, to fully restore or repair the damage

Table 2—Determination of dam's potential impact classification

Assessed damage level (from table 1)	Population at risk: 0	1–10	11–100	more than 100	Potential loss of life
Catastrophic	High potential impact	High potential impact	High potential impact	High potential impact	No persons
	N/A (*see* note 1)	High potential impact	High potential impact	High potential impact	One person
	N/A (*see* note 1)	High potential impact	High potential impact	High potential impact	Two or more persons
Major	Medium potential impact	Medium potential impact	High potential impact	High potential impact	No persons
	N/A (*see* note 1)	Medium potential impact	High potential impact	High potential impact	One person
	N/A (*see* note 1)	High potential impact	High potential impact	High potential impact	Two or more persons
Moderate	Low potential impact	Low potential impact	Medium potential impact	Medium potential impact	No persons
	N/A (*see* note 1)	Medium potential impact	Medium potential impact	Medium potential impact	One person
	N/A (*see* note 1)	High potential impact	High potential impact	High potential impact	Two or more persons
Minimal	Low potential impact	Low potential impact	Low potential impact	Low potential impact	No persons
	N/A (*see* note 1)	Medium potential impact	Medium potential impact	Medium potential impact	One person
	N/A (*see* note 1)	High potential impact	High potential impact	High potential impact	Two or more persons

Note
1 Not applicable. The population at risk is zero, therefore there is no potential loss of life.

Appendix 3 – Over-design Events

Hawkes Bay February 2023 – Cyclone Gabrielle:

The following information on rainfall for this event is provided in the Report of the Hawke's Bay Independent Flood Review, July 2024.

2.1 Rainfall

Extraordinary depths and intensities of rain fell during Cyclone Gabrielle throughout the Hawke's Bay region. From HBRC data provided to us, the largest depth of rainfall was measured at the Glengarry recorder site in the Esk Valley with a total 546 mm. Approximately 400 mm fell in 12 hours at a maximum intensity of 56 mm per hour (see Figure 2.3).

A number of other sites experienced rainfall depths exceeding 400 mm in 30 hours, including sites in the Wairoa, Tutaekuri and Ngaruroro catchments.

Many parts of the region experienced significantly more rainfall than that which occurred during Cyclone Bola in March 1988, especially in Pōrangahau, where the amount of rainfall was double that of the most intense 24-hour period during Bola.

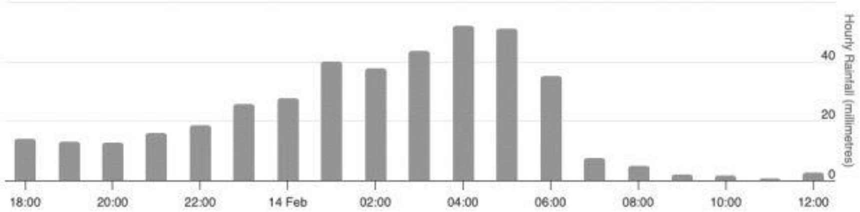


Figure 2.3 Hourly Rainfall Glengarry 1800 hrs 13 Feb – 1200hrs 14 Feb 2023[15]

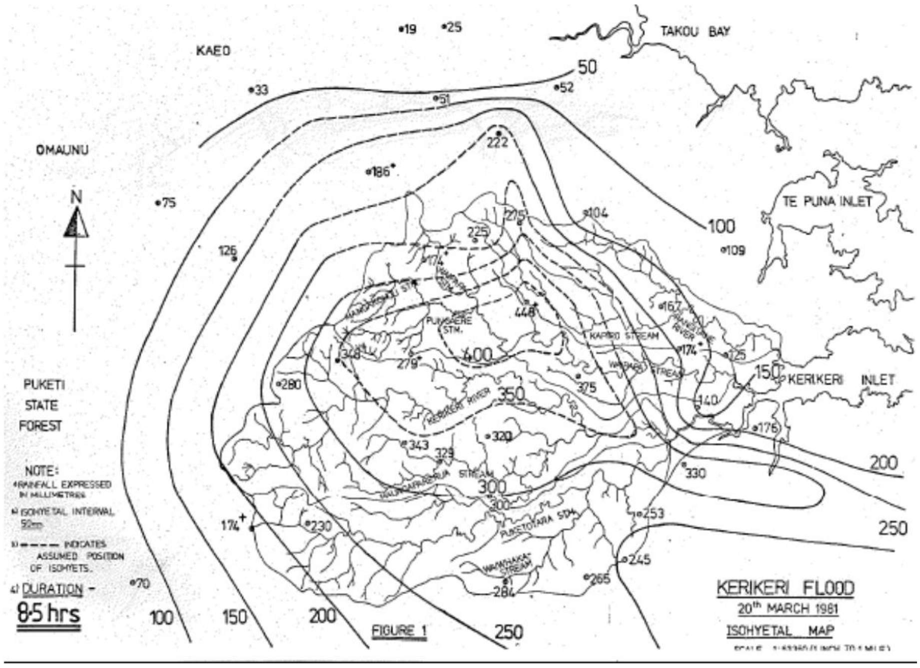
From Section 2.2 - River Flows

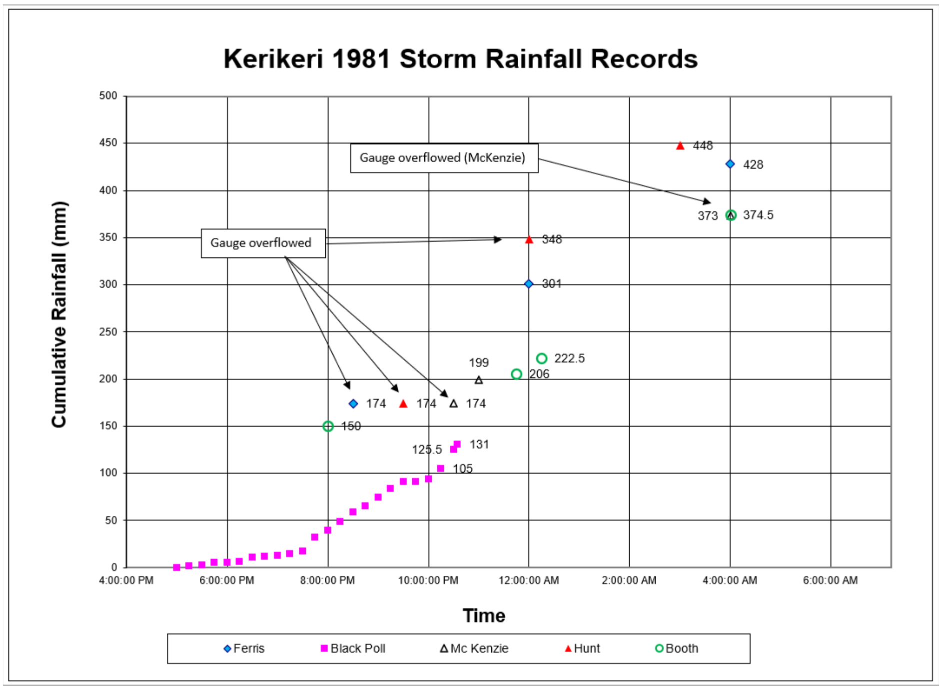
For the purposes of this report, the flood return period based on the pre-2023 flood frequency analysis is quoted, because that was the information in the summary statistics in use by HBRC at the time. A summary of the major rivers with the highest flood return periods is provided in Table 2.2. The revised figures (which include the influence of Cyclone Gabrielle) subsequently produced by NIWA are also shown, for comparison.

Table 2.2 Summary of estimated flood flows and return periods[20]

River Site	Flood flow	Flood return period pre-cyclone	Flood return period post-cyclone
Wairoa River at Marumaru	4,100 m^3/s	250 years	120 years
Esk River at Waipunga	2,175 m^3/s	220 years	180 years
Tutaekuri River at Puketapu	4,800 m^3/s	980 years	400 years
Ngaruroro River at Fernhill	6,000 m^3/s	> 1000 years	480 years
Waipawa River at RDS	1,810 m^3/s	> 1000 years	120 years
Pōrangahau River at Saleyards	1,590 m^3/s	> 1000 years	80 years

Kerikeri March 1981 storm





Note: MWD report identified that Hunt, Ferris and McKenzie rainfall gauges were within radius of 200m. Given Ferris reported his rain gauge overflowed at 20:30, it is likely that Hunt missed 1 hour of rainfall (20:30-21:30), and McKenzie missed 2 hours (20:30-22:30). Hunt and McKenzie rain gauges also overflowed later in the storm.

Appendix 3: Filed letter concerning extrapolation of rating curves for Maungaparerua rating curve.

Ministry of Works and Development
Commercial Division

Head Office, Vogel Bldg., Aitken Street
Box 12 041, Wellington North
Telephone 729 929. Telex NZ 3844

Inquiries to

Date 14 January 1988

Our ref 92/11/4/1
Your ref

The Manager
Ministry of Works and Development
Box 641
WHANGAREI

ATTENTION : 1 Mr K D Russell
2 Mr R Tasker

MAUNGAPARERUA RIVER - FLOOD MARCH 1981

As discussed Tasker/Freestone, please find a calculation sheet attached which gives details of our estimate for the March 1981 flood at the Maungaparerua at Tyrees Ford site (3506).

If you choose to accept this estimate for the March 1981 flood, then the last two pairs of co-ordinates on your rating table should be replaced with the following: (mm/ml)

Stage	3000	4230
Q	92,600,000	225,000,000

Furthermore if the maximum stage value of 4.23 m was filed in March 1981 as time series data (rather than a comment) with a gap element either side of it then the record for this very large flood would be complete.

It may be possible to make a better estimate for the '81 flood in the future when some high stage check gaugings are obtained. It would be useful when these gaugings are carried out, to also measure the downstream head so that a measure of submergence can be made similar to that made for the 1981 flood. A measure of the degree of submergence in centre channel would be useful too even if only obtained by photographs.

Thank you for your help.

H J Freestone
for Commissioner of Works

Encl

Ministry of Works and Development		
Office: Power, Inv. Hydrology	Job No. .... File	Sheet No. ....
Computed: M.Z. 14 / 1 / 1987 H.J. Freestone	Description: Site 3506 Maungaparerua @ Tyrees Ford Flood 19 March 1981	PROJECT ....
Checked .... / /19		

Before Commencing the following Calculation I obtained data from the TIDEDA comments for the Site and from Mr. R.A. Tasker, MWD Whangarei.

RE ESTIMATE of MAX Q for Flood of 19.3.1981

1) Peak Gauge ht.: [H] 4.23m
2) Ht. above top of Structure: 1.04m

3) Q at 4.23m by using Weir rating extended: 283 m³/s
4) Reduction in rating flow to allow for one bank being near vertical and the other not being in the form of an end contraction. ∴ Correction =
Area @ GH 4.23m = *55.6 m² Ends 5.30 1.06m 1.8 5.30

Correct area by reducing by ends by 85% ∴ new area = 50 m²
Correction to Max Q = 50/55.6 × 283 : 254 m³/s

5) Downstream Head (Measure) - GH Ht : [d] 1.96 m
6. Percent drowning of Weir 1.96/4.23 (d/H) 46%

7. Correction Coefficient for Submerged Weirs (Table 13, US Department of the Interior, Water Manual, 1975) 0.865

8. Correction for submergence (drowning) 254 × .865 220 m³/s
9. Mean Velocity (using Max area) 3.96 m/s

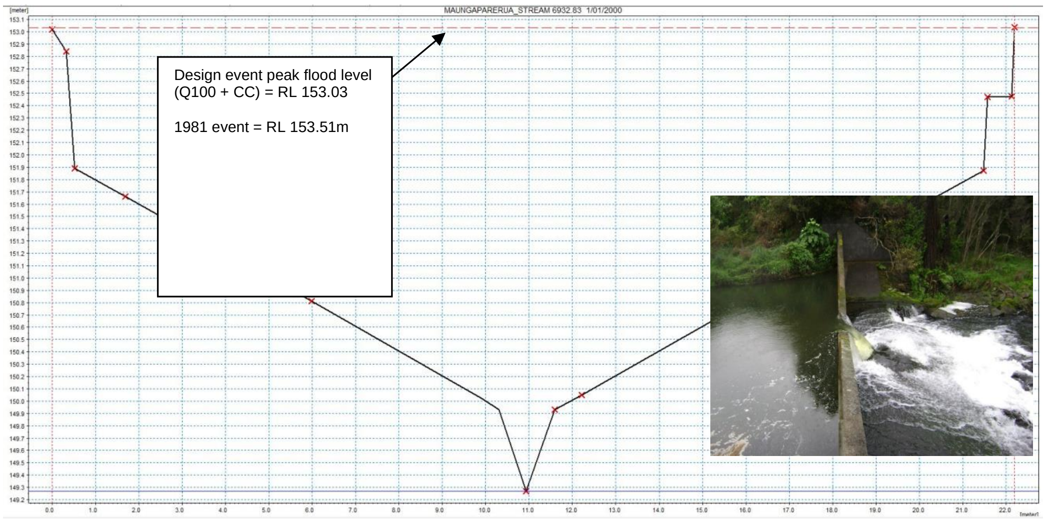
10 Bypass Water (Estimate) 5 m³/s

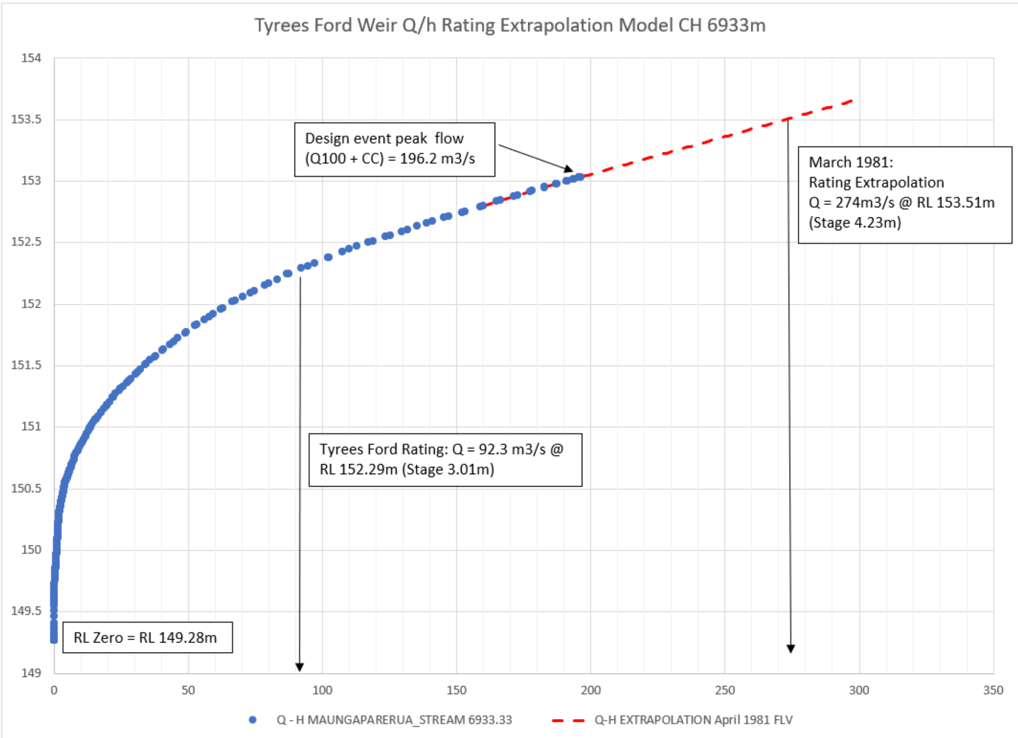
11. Estimate of Total Peak Flow (8+10) = 220+5 = 225 m³/s

* My cross check in this area for a standard compound weir of this type puts the area between 60 and 70 m². Q not effected if the area is changed but it would alter V

P.W. 377 (Rev. 3/80) (CALCULATION SHEET)

Flood Model Cross Section – Maungaparerua at Tyrees Ford





Appendix 3 (Continued) – Flow Frequency Analysis – Tyrees Ford

Based on the estimated 1981 flow of 225m³/s

```
Attachment 5 - Frequency Analysis of Site Record, Tyrees Ford

Hilltop Hydro Version 6.42                                        26-Aug-2015
~~~ FRED ~~~
Source is W:\LandMngt\riverworks\HILLTOP FILES\ZZ COPY OF HILLTOP DATA\Tyrees Ford.hts
Flow (m3/s) at Maungaparerua at Tyrees Ford
From  1-Jan-1968 00:00:00 to 30-Dec-2014 24:00:00
Moments L1= 52252.961      L2= 14540.933      T3= 0.264       T4= 0.268
Location  = 0.462E+05 Scale = 0.129E+05 Shape =-0.264       100yr/2.33yr = 3.240

  12 mth            Recorded          maximum            -- GLO    Distribution --
 partition            value           measured                  1.96      ann. return
  starts               at                                        std.    prob. period
                                                                 dev.      1/y     y
                                                 300310.675                0.001 1000
                                                 249580.041                0.002  500
01-Jan-1981 19-Mar-1981 22:00:00 225035.078 A  225035.078                0.003  339.6
                                                 195216.402                0.005  200
                                                 161895.579                0.010  100
                                                 133995.044                0.020   50
01-Jan-2007 29-Mar-2007 12:15:00 103940.500 B  103940.500                0.050   20.1
                                                 103729.601                0.050   20
01-Jan-1974 23-Feb-1974 14:00:00  88828.086 C   88828.086                0.085   11.7
                                                  84658.836                0.100   10
01-Jan-2014 12-Jul-2014 01:00:00  78978.570 D   78978.570                0.125    8.0
01-Jan-1984 30-Mar-1984 03:21:00  75498.680 E   75498.680                0.145    6.9
01-Jan-1975 14-Jun-1975 08:00:00  70197.719 F   70197.719                0.181    5.5
01-Jan-1971 11-Mar-1971 10:45:00  69587.797 G   69587.797                0.185    5.4
01-Jan-2009 28-Feb-2009 00:30:00  69587.797 H   69587.797                0.185    5.4
01-Jan-1970 28-Oct-1970 07:45:00  69327.477 I   69327.477                0.187    5.3
01-Jan-2011 18-Jun-2011 01:00:00  68981.391 J   68981.391                0.190    5.3
                                                  67802.034                0.200    5
01-Jan-1989 06-Jan-1989 08:00:00  67450.172 K   67450.172                0.203    4.9
01-Jan-1987 21-Nov-1987 20:30:00  64433.406 L   64433.406                0.231    4.3
01-Jan-2001 12-Apr-2001 22:45:00  63518.141 M   63518.141                0.241    4.2
01-Jan-1976 13-Jan-1976 07:30:00  59521.680 N   59521.680                0.286    3.5
01-Jan-1973 22-Jul-1973 18:45:00  56021.906 O   56021.906                0.333    3.0
01-Jan-1999 30-Apr-1999 12:45:00  55873.496 P   55873.496                0.335    3.0
01-Jan-1997 01-Jun-1997 19:15:00  55873.496 Q   55873.496                0.335    3.0
01-Jan-2012 19-Mar-2012 06:00:00  55061.734 R   55061.734                0.347    2.9
01-Jan-1979 31-Jul-1979 23:23:59  55061.734 S   55061.734                0.347    2.9
01-Jan-2008 26-Jul-2008 12:30:00  51467.637 T   51467.637                0.404    2.5
01-Jan-1988 28-Nov-1988 11:15:00  51339.137 U   51339.137                0.406    2.5
01-Jan-1983 09-Jun-1983 01:26:22  51256.980 V   51256.980                0.407    2.5
                                                  49961.713                0.430    2.33
01-Jan-1986 25-Jan-1986 17:30:00  48299.660 W   48299.660                0.460    2.2
01-Jan-1968 08-Apr-1968 00:30:00  47829.223 X   47829.223                0.468    2.1
01-Jan-1998 14-Jul-1998 18:15:00  47628.547 Y   47628.547                0.472    2.1
01-Jan-1995 25-Oct-1995 19:00:00  47561.781 Z   47561.781                0.473    2.1
01-Jan-2003 02-May-2003 18:30:00  45200.000 a   45200.000                0.519    1.9
01-Jan-1980 15-Mar-1980 09:25:14  43949.797 b   43949.797                0.544    1.8
01-Jan-1985 03-Sep-1985 19:45:00  43148.609 c   43148.609                0.560    1.8
01-Jan-1972 09-Aug-1972 01:30:00  40858.371 d   40858.371                0.607    1.6
01-Jan-2002 18-Jun-2002 23:30:00  39800.410 e   39800.410                0.629    1.6
01-Jan-1996 02-Sep-1996 08:00:00  39567.656 f   39567.656                0.633    1.6
01-Jan-1969 10-Jun-1969 01:30:00  38817.098 g   38817.098                0.649    1.5
01-Jan-1977 28-Jun-1977 07:53:36  36564.242 h   36564.242                0.695    1.4
01-Jan-1978 16-Jun-1978 17:44:40  33763.148 i   33763.148                0.751    1.3
01-Jan-1992 06-Jun-1992 00:30:00  30762.188 j   30762.188                0.807    1.2
01-Jan-2000 11-May-2000 23:30:00  29687.291 k   29687.291                0.825    1.2
01-Jan-1990 07-Aug-1990 06:30:00  28501.000 l   28501.000                0.845    1.2
01-Jan-2006 26-Mar-2006 20:30:00  28454.191 m   28454.191                0.845    1.2
01-Jan-2013 22-Sep-2013 01:00:00  27862.951 n   27862.951                0.855    1.2
01-Jan-2004 28-Feb-2004 16:30:00  26528.758 o   26528.758                0.874    1.1
01-Jan-1994 17-Jul-1994 08:15:00  26093.396 p   26093.396                0.880    1.1
01-Jan-1993 18-Sep-1993 24:00:00  23299.783 q   23299.783                0.915    1.1
01-Jan-2005 11-Jul-2005 15:15:00  20674.426 r   20674.426                0.942    1.1
01-Jan-2010 02-Aug-2010 11:00:00  18608.431 s   18608.431                0.958    1.0
01-Jan-1991 09-Aug-1991 10:30:00  17951.053 t   17951.053                0.963    1.0
01-Jan-1982 02-Oct-1982 00:59:58  17634.520 u   17634.520                0.965    1.0
                          Mean = 52252.961
```

Flow frequency analysis for Tyrees Ford Site. Note flows are based on the historical record and do not allow for any future climate factors. The record assessed is up to December 2014.

Subject: - Kerikeri – Waipapa River Working Group Integration with FNDC Kerikeri – Waipapa Spatial Plan

The main common interest of these two groups can be summed up in one word – **Water**

Water is an essential element to service the aspirations of the proposed Kerikeri-Waipapa Spatial Plan and falls into the following distinct categories

(1) Not enough – (2) Too much – (3) Downstream use - (4) End disposal

(1) Not enough is in relation to the future water supply of both Kerikeri and Waipapa communities. The proposed plan identifies various growth options of 20-40% with a population to exceed 25,000 within 30 years. Currently approx. 70% the reticulated water supply is sourced from an untenable Waingaro Irrigation dam, the balance of the supply is from a limited Resource Consent from the Puketotara Stream. Both sources are insufficient at the present time, and availability could be further threatened with the increased draw down by irrigation water by the horticulture sector. The only other potential future water source for Kerikeri and Waipapa could be from utilizing the local Kerikeri River area catchment options. The other possible future source would be from the under construction Otawere Water Storage Reservoir at Waimate North. This supply would involve a very extensive and costly delivery option to Kerikeri and Waipapa

(2) Too much is in relation to the well documented flooding potential that would devastate Waipapa and most communities downstream when the Kerikeri Waipapa and the Puketotara reaches a peak flood flow condition. The accelerated growth that has occurred over recent years has placed these communities and businesses at extreme risk. Should a flood of the recent Gabriel intensity, be experienced in the local Kerikeri River area catchments, it would be catastrophic. The loss and damage of State Highway 10 travel access would be one of the immediate repercussions, The potential loss of life, property, infrastructure, and the environment, extending right through to the lower river settlements, would be extensive.

(3) Downstream use If a Kerikeri river flood mitigation dam was installed as previously proposed by the NRC Waipapa – Kerikeri working group, it would offer extraordinary support to the vision of the proposed Kerikeri – Waipapa Spatial Plan. Downstream use would enable a reservoir dam water to be used for a multiple water supply services for Kerikeri-Waipapa planned growth, while at the same time providing river flood protection management. There may be an opportunity to provide recreational use of the proposed reservoir dam.

(4) End Disposal The end disposal of water is after the accumulated use of the water provided, and in terms of the proposed growth in the Kerikeri – Waipapa Spatial Plan, it would be the essential service element of Plan that would allow the for the intensifying of housing development. It would allow for not only a water supply but a functioning wastewater disposal system and a fire protection service. The eventual drainage would be to the receiving environment.

Conclusion: -

A strategic directional effort should be for the NRC and the Kerikeri – Waipapa Working Group to work closely and support each other with the aspirations of the Kerikeri-Waipapa Spatial Plan. This will allow for a co-ordinated approach to provide the technical input support into the provisions of attracting the funding resources to make the Plan operational

Fred Terry

Infrastructure Consultant 23rd March 2025