Memo

From	**Christian Zammit**
To	Luke Fullard and Dr Amy Lennard (Horizons Regional Council)
CC	
Date	30 October 2024
Subject	Summary of the workshop discussions held at NIWA Wellington on 8th August 2024

Summary

This memo summarises the discussions from a workshop held both in-person and online at NIWA in Wellington on August 8, 2024. The notes were compiled by NIWA and Horizons Regional Council members, Dr. Amy Lennard and Luke Fullard.

Participants

Participants included NIWA hydrologists and climate scientists (Dr Christian Zammit and Dr Peter Gibson), representatives from the Ministry for the Environment (MFE), and stakeholders from various regional councils. A complete list of invitees and participants is provided in Appendix A.

Workshop purpose

The workshop aimed to establish a consistent method for determining and characterising the impacts of climate change on mid to low surface water flows across New Zealand.

Agenda overview

The workshop agenda included a presentation by Christian Zammit on an MFE-funded pilot study that compared the impacts of CMIP5 and CMIP6 on hydrological regimes. Following this presentation, the workshop was organised into three main sections listed below and detailed in the remainder of this memo:

- **Identifying Questions for Regional Councils**: This section aimed to develop a consensus among regional councils regarding their needs and the associated hydro-climate variables for which information would be requested.
- **Nationally Consistent Information**: Participants discussed what information could be provided using a consistent approach across all regions.
- **Next Steps for Information Development**: The group considered the subsequent steps necessary for developing this information.

Conclusions

The workshop participants agreed on the need to update New Zealand's hydrological projections to reflect the latest understanding of climate change. Key considerations and approaches for undertaking such an update were discussed.

Next Steps

The proposed next step is to develop an Envirolink Tool proposal to seek funding for this work. Subsequently, a preproposal was lodged, focusing on characterising the potential impacts of climate change on water security in New Zealand.

Questions that Regional Councils need to have answered and what variables are needed

Questions to be answered in the context of climate change impact assessment

To support their functions, the following questions need to be addressed in the context of climate change impact assessment:

- **Changes in Low Flow Statistics**: What changes occur in low flow statistics and metrics over time under different warming scenarios across all Regional Council activities?
- **Precipitation Patterns**: How do changes in precipitation patterns affect irrigation water demand modelling over time and under different warming scenarios, particularly in relation to water consenting and allocation activities?
- **Flow Harvesting Metrics**: What changes occur in flow harvesting hydrological metrics, such as the future availability of harvestable water, which needs to be defined across Regional Councils?
- **Drought Characteristics**: How can changes in drought characteristics be determined and described? This includes understanding the climate drivers that generate droughts and their specific characteristics (e.g., amplitude versus temporal signature). It also involves attributing changes to climate change versus climate variability (e.g., El Niño/La Niña explaining 10–20% of climatology).
- **Impacts of Climate Non-linearity**: What are the impacts of climate non-linearity on hydrological metrics, and what are the implications for Regional Council operations?
- **Merging Climate Change Impacts**: How can the impacts of climate change on climate and hydrology be integrated to provide comprehensive answers for long-term and economic planning activities?
- **Extreme Weather Considerations**: Impacts of climate change on extreme weather and climate, including flood characterisation, will be addressed in a separate workshop focused on resilience to climate extremes and infrastructure planning.

Temporal characterisation needed

Regional Councils require information presented at the following time resolutions to meet their internal data needs:

- Information should be provided at annual and seasonal time scales across both reference and future time periods (this is a minimum requirement).
- Information must characterise the time of emergence of the climate signal to distinguish impacts due to climate change from those caused by current or increased climate variability.

Hydrological metrics needed

Regional Councils have requested information on the following hydrological metrics to fulfil their obligations:

- **Flow Harvesting Metrics**: Development of metrics across all Regional Councils to identify potential shifts in the availability of flow harvesting.
- **Flow Characteristics**: Changes in flow characteristics associated with ecological and geomorphological assessments, such as Fre3[1], Fre5, and Fre7.

[1] FreX: flushing flows associated with frequency of events that exceeds X times the median flow

- **Hydro-climate Metrics**: Changes in hydro-climate metrics related to biological disturbances.
- **Low Flow Events**: Characterisation of changes in the duration and frequency of low flow events.
- **Water Supply Security**: Changes in the security of supply and water resource allocation.

The change in the hydrological metrics need to be defined as:

- Changes in terms of mean (currently used in water plans), median (more representative of central tendency, not currently in use in water plans), and percentiles of exceedance or non-exceedance (related to uncertainty characterisation or ecological flow thresholds).
- Peak over threshold for high and low flows (related to water availability) to understand changes in the frequency of hydrological events (e.g., changes in the number of days below historical low flow thresholds).

Hydrological variables to be considered

Based on the questions and hydrological metrics requested by Regional Councils, the following hydrological variables are required, in addition to climate variables needed for harmonising climate and hydrological characterisation:

- **River Discharge**: Measurement of river flow.
- **Soil Moisture**: Assessment of moisture content in the soil.
- **Soil Infiltration**: Evaluation of how water enters the soil.
- **Land Surface Recharge**: Used as a proxy for groundwater system responses to climate change.
- **Groundwater Level**: Currently not available through a nationally consistent approach, as direct conversion from land surface recharge is challenging.
- **Current Characteristics from CMIP5 Assessment**: Including Mean Annual Flood, Mean Flow, Q95, and 7-day Mean Annual Low Flow.
- **Water Availability Measures**: Assessment of water availability during stress periods, including changes in duration, onset, and offset.
- **Stream Temperature**: Linked to environmental flows, because greenhouse gases directly affect water radiative heat loss. Regional Council observation datasets indicate that rivers are warming faster than oceans.

Additional needs identified by Regional Councils

- **Understanding Climate Drivers**: A better understanding of the climate drivers that generate historical large droughts (from climate to agricultural drought) is needed to reduce uncertainty. Can reliable predictions be made without understanding these drivers?
- **Co-development of Hydrological Metrics**: Collaboration with end-user communities (from local catchment groups to professional societies) is essential, as different groups use the same hydrological metrics for different purposes.
- **Clear Communication**: All assumptions and limitations must be communicated clearly.
- **Characterisation of Surface Water Flow Cease**: Understanding when surface water flows cease within rivers.

- **Change in Extremes**: Characterisation of cease flow characteristics under climate change due to warming temperatures. This includes changes in the magnitude, frequency, and duration of extreme wet and dry events, requiring a common characterisation of extreme events based on infrastructure considerations or risk assessments.
- **Final Choice of Hydrological Characteristics**: Selection of hydrological characteristics associated with flow regimes should be based on ecological functions (Poff et al. 1997).
- **Coupling Climate Change to Land Cover Change**: Understanding how climate change interacts with changes in land cover.

Characterisation of uncertainty

Climate change projections are inherently uncertain. Key questions include:

- How should uncertainty be characterised?
- How can we clearly identify what can be stated with certainty?
- How can we link scientific findings under climate change (which are inherently uncertain at multiple levels) with planning decisions and policy development?
- What hydrological and climate variables are we most confident about? Which catchments or river basins have high confidence in the analysis?
- How can we effectively communicate uncertainty across Regional Council functions and to the public?
- How can we convey uncertainty throughout the entire modelling chain and into decision-making? (Climate scientists often use model spread to measure certainty.)

What information can be provided using a nationally consistent approach across all regions

This section aims to identify the methodology, reporting requirements, assumptions, limitations, and synergies with existing national-scale modelling investigations (past, present, and future).

Proposed modelling methodology

- **Choice of Climate Dataset**: Consideration of which climate dataset to use or whether to adopt an ensemble approach.
    - **Bias-Corrected Data**: Downscaled to VCSN (5 km spatial resolution), provided at a daily time step for a limited number of climate variables, including precipitation, maximum and minimum temperature, and potential evapotranspiration.
    - **Non-Bias-Corrected Data**: Available at a 12 km spatial resolution, provided at an hourly time scale for all climate variables.
- **Climate-Hydrology Modelling Chain**: An ensemble approach is preferred to minimise model dependency in the assessments.
- **Common Methodology**: A unified methodology for bias correction and assessing climate change impacts across the entire flow regime (from high flow to low flow) is desired. This methodology should be applicable to locations with or without observations during the reference period.
- **Output of the Analysis**: The analysis should report the following:
    - Changes in magnitude, expressed in both absolute and relative terms at specific locations.

- Changes in magnitude and duration relative to the reference period at those locations.
- Characterisation of changes in frequency or probabilities, conducted spatially.
- Assessment of simulation accuracy over the near future time period (i.e., the CMIP6 future time period for which streamflow observations are available, specifically from 2015 to 2024).

- **Unique Calculation Methods**: A distinct method for calculating changes across all hydro-climate metrics is necessary. Current methods used within Regional Councils rely on historical observation time series analysis, which may lead to inconsistencies across different regions for the same hydro-climate metric.
- **Robustness of Future Datasets**: Consideration of issues related to the robustness of future datasets for calculating hydrological statistics, including error bars and a Bayesian approach with prior information.
- **Water Use and Availability Analysis**: The analysis should characterise water use and availability to provide a consistent view across changing hydrological regimes and resource availability.
- **Linking Climate Change Impacts**: Regional Councils express a desire for analysis that links climate change impacts on water allocation to riverine ecological health.
    - **Answer**: This is likely out of scope due to the diverse methods used among Regional Councils to assess ecological health.
- **Characterising Financial Risks**: There is also a desire from Regional Councils to characterise financial risks.
    - **Answer**: This is deemed out of scope for the purpose of the tool.

Presentation of the analysis

- **Simplicity in Reporting**: The High Intensity Rainfall Design System (HIRDS) presents results in terms of change per degree of warming. Can this methodology be applied to the proposed tool?
    - **Answer:** Reporting the analysis in terms of warming levels (i.e., per degree) is challenging within the context of the tool. This difficulty arises because the reference period starts in 1850, a time before significant climate warming occurred. In contrast, the Inter-Governmental Panel on Climate Change (IPCC) methodology begins in the 1960s, when warming was evident. Consequently, it is difficult to separate the impacts of pre-1960 climate warming from the analysis.
- **Communication of Changes**: A clear communication package should be developed to outline the “do’s and don’ts” of the analysis.
- **Characterisation of Water Availability**: The proposed tool must characterise changes in available water across different uses. Therefore, it is requested that the absolute change in water availability be reported per unit area.
- **Perspective on Water Consenting Activities**: The proposed tool should present information from the perspective of water consenting activities (up to 20–30 year consents) compared to policy statements (which have a plan life of 10 years and are revisited every three years).

- **Climate Regions Presentation**: The analysis should be presented in relation to climate regions, ensuring a consistent message across those regions.

Regional scale assessment versus bespoke local assessment

- **Different Needs Addressed**:
  - The regional scale assessment provided by the proposed tool aims to give an overview of the potential impacts of climate change across the region or reporting management unit. It will utilise a common dataset of information across the region or reporting unit.
  - Bespoke assessments are developed by third parties to address specific questions based on local high-resolution information.
  - The proposed Envirolink tool does not aim to resolve this issue but instead presents information using consistent datasets and estimation methods.
- **Internal and External Use**: The tool is designed to provide information that can be used for both internal and external purposes.
- **Addressing Different Questions**: Different sectors may pose varying questions. It is important to clarify how this diversity is addressed or explicitly state that it is not part of the assessment.

Hydrological model available for reach to national scale assessment

The modelling chain used in the tool is proposed to be based on the framework developed as part of the New Zealand Water Modelling project. This framework utilised the TopNet hydrological model suite (Clark et al. 2008), which has been employed in previous national-scale water resource and climate change impact assessments (Collins and Zammit 2016; Collins 2020).

- **Alignment with Other Projects**: The hydrological model will align with the Mā te haumaru ō te wai project and the National Flood Awareness System project (Cattoen et al. 2022).
- **Standardisation by Temperature Change**: There is potential for standardisation by temperature change to ensure uniformity across existing national tools (e.g., HIRDS) used within the regional sector.
- **Hydrological Model Ensemble**: The hydrological model ensemble has already been a priori parameterised across New Zealand, with the performance of this parameterisation benchmarked (Booker and Woods 2014; McMillan et al. 2016).
- **Limitations**:
  - The surface water model has limited knowledge of groundwater and is not connected to regional groundwater systems. However, land surface scenarios can be linked (one way) with national steady-state models to understand changes in groundwater levels under natural conditions.
  - Current models do not allow for changes in land cover over time, but they can be run for different land cover scenarios. This capability could be used to explore the relationship between changes in land cover and changes in baseflow conditions.

Next steps

- **Envirolink Tool Proposal**: The proposal for the Envirolink Tool will receive support from Horizons and Waikato Regional Councils, as well as Environment Canterbury and Environment Southland.

- **Realistic Programme Development**: It is essential to create a realistic work programme that fits within a one-year project duration. The goal is to produce the tool within this timeframe while managing expectations appropriately. The proposed tool is intended to provide information rather than to resolve water allocation or consenting investigations related to climate change.
- **Focus on Water Allocation**: The emphasis will be on water allocation within the lifespan of one or two plans, covering assessments of up to 30 years, rather than conducting a comprehensive assessment extending to the end of the century.
- **Guidance for Tool Development**: As part of developing the tool, clear guidance must be established on how to use the results generated. This guidance should also explain how the tool links with existing models used by Regional Councils, bespoke local models developed by third parties, and existing tools (such as NZ Rivermaps and National Flood Frequency) or ongoing projects (e.g., Mā te haumaru ō te wai).
- **Graphical User Interface (GUI)**: A GUI is necessary for Regional Councils to access the generated information. For ease of maintenance and simplicity, it is likely that the GUI will be based on an RShiny app. The app must address the spatial resolution of the information and present a table of changes in hydrological statistics. However, the GUI will not provide access to time series data; this data will be delivered separately to each Regional Council along with appropriate documentation and metadata.

References

Booker, D. J., Woods, R. A. (2014) Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. *J. Hydrol.*, vol. 508, pp 227-239. http://dx.doi/org/10.1016/j.hydrol.2013.11.007

Cattoën, C., Conway, J., Fedaeff, N., Lagrava, D., Blackett, P., Montgomery, K., Shankar, U., Carey-Smith, T., Moore, S., Mari, A., Steinmetz, T., & Dean, S. (2022). A national flood awareness system for ungauged catchments in complex topography: The case of development, communication and evaluation in New Zealand. *Journal of Flood Risk Management*, e12864. https://doi.org/10.1111/jfr3.12864

Clark, M.P., Rupp, D.E., Woods, R.A., Zheng, X., Ibbitt, R.P., Slater, A.G., Schmidt, J., Uddstrom, M.J. (2008) Hydrological data assimilation with the ensemble Kalman filter: Use of streamflow observations to update states in a distributed hydrological model. *Advances in Water Resources*, 31(10): 1309-1324. 10.1016/j.advwatres.2008.06.005

Collins, D. (2020) New Zealand river hydrology under late 21st century climate change. *Water*, 12, 2175; doi:10.3390/w12082175

Collins, D., Zammit, C. (2016) Climate change impact on agricultural water resources and flooding. Prepared for the Ministry of Primary Industries. Client Report 2016114CH.

McMillan, H.K., Booker, D.J., Cattoen, C. (2016) Validation of a national hydrological model. *Journal of Hydrology*, 541: 800-815. 10.1016/j.jhydrol.2016.07.043

Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., Sparks, R. E., Stromberg, J. (1997) The natural flow regime: A paradigm for river conservation and restoration. BioScience, 47(11), 769-784. https://doi.org/10.2307/1313099

Appendix A: List of invitees and participants to the workshop

The following list provides the details of the people invited to the workshop as well as their response to the invitation.

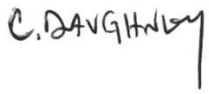
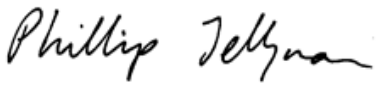
Name	Organisation	Response
Luke Fullard	Horizons Regional Council	Accepted
Amy Lennard	Horizons Regional Council	Accepted
Chris Daughney	NIWA/Regional Council	Accepted
Mike Scarsbrook	Waikato Regional Council	Declined
Ed Brown	Waikato Regional Council	Declined
Ruth Buckingham	Waikato Regional Council	None
Megan Oliver	Greater Wellington Regional Council	Declined
Evan Harrison	Greater Wellington Regional Council	Declined
David Hipkins	Greater Wellington Regional Council	None
Annabel Beattie	Hawkes Bay Regional Council	None
Fiona Shanhun	Environment Canterbury	None
Tim Davie	Environment Canterbury	None
Davina McNickel	Environment Canterbury	Declined
Fiona Thomson	West Coast Regional Council	None
Peter Gibson	NIWA	Accepted
Rob Donald	Bay of Plenty Regional Council	Declined
Rob Smith	Tasman District Council	None
Helen Gerrard	Taranaki Regional Council	None
Thomas Mcelroy	Taranaki Regional Council	Declined
Craig Pickford	Taranaki Regional Council	None
Victoria McKay	Taranaki Regional Council	None
Murry Cave	Gisborne District Council	None
Amber Dunn	Gisborne District Council	None
Paul Murphy	Gisborne District Council	Accepted
Jocelyne Allen	Gisborne District Council	None
Alan Johnson	Marlborough District Council	None
Jonathan Benge	Auckland Council	Declined
Kolt Johnson	Auckland Council Auckland Council	Accepted
Sietse Bouma	Auckland Council	None
Iain Maxwell	Hawkes Bay Regional Council	Declined
Bill Dyck	Envirolink	None
Maree Patterson	Horizons Regional Council	Declined
Megan Carbines	Auckland Council	None
Jon Roygard	Horizons Regional Council	Declined
Coral Grant	Auckland Council	Declined
Sarah lomas	Auckland Council	None
Jacqueline Lawrence-Sansbury	Auckland Council	None

Name	Organisation	Response
Graeme Campbell	Greater Wellington Regional Council	None
Stefan Beaumont	Nelson City Council	Accepted
Jason Donaghy	Northland Regional Council	Declined
Emmah	Northland Regional Council	None
Karen Wilson	Environment Southland	Accepted
John Prince	Environment Southland	None
Tom Dyer	Otago Regional Council	None
Clive Appleton	Nelson City Council	Accepted
David Measures	Nelson City Council	None
Sarah Pearson	Marlborough District Council	Tentative
Suzanne Gabites	Environment Canterbury	Accepted
Peter Davidson-8456	Marlborough District Council	Accepted
Suhas	Northland Regional Council	Accepted
Jen Dodson	Environment Canterbury	Accepted
Hamish Graham	Environment Canterbury	None
Bram Mulling	Greater Wellington Regional Council	Accepted
Markus Dengg	Otago Regional Council	Accepted
Dave West	Department of Conservation	Accepted
Breda Savoldelli	Bay of Plenty Regional Council	None
Darien Kissick	Greater Wellington Regional Council	None
Theodore Kpodonu	Auckland council	Accepted
Bridget Bosworth	Gisborne District Council	None
Kohji Muraoka	Ministry for the Environment	None
Penny H	Northland Regional Council	None
Daniel Clark	Environment Canterbury	Accepted
Mike Thompson	Greater Wellington Regional Council	None
Fiona Jansma	Taranaki Regional Council	Accepted
Paul	Gisborne District Council	None
Elaine Moriarty	Environment Canterbury	Declined
Sungsoo Koh	Waikato Regional Council	Accepted
Thomas Wilding	Waikato Regional Council	Accepted
Ticha Gonah	Northland Regional Council	Declined
Nixie Boddy	Department of Conservation	Declined
Jenny Christie	Ministry for the Environment	Tentative
Kohji Muraoka	Ministry for the Environment	None
Brent Watson	Horizons Regional Council	Tentative
Carolyn Mander	Ministry for the Environment	None
Carl Howarth	Ministry for the Environment	Accepted
James King	Ministry for the Environment	Tentative
Sean Hudgens	Ministry for the Environment	Declined
Manas Chakraborty	Northland Regional Council	Declined
Steven Cornelius	Waikato Regional Council	Accepted
Divesh Mistry	Gisborne District Council	Declined

Name	Organisation	Response
Jeanine Topelen	Environment Canterbury	Accepted
Glenys Kroon	Bay of Plenty Regional Council	Accepted
Allen Temple	Northland Regional Council	Accepted
Alan Bee	Northland Regional Council	Accepted
Rick Liefting	Waikato Regional Council	Accepted
Adrian Meredith	Environment Canterbury	Accepted
Christian Zammit	NIWA	Accepted
Andrew Tait	NIWA	Declined
Chris Jenkins	Environment Southland	Tentative
Charlotte Tomlinson	Marlborough District Council	Accepted

NIWA Report No: 2024326CH
NIWA Project: ELF25501

Revision	Description	Date
Version 1.0	Final version sent to client	30 October 2024

Quality Assurance Statement		
	Reviewed by:	Chris Daughney
	Formatting checked by:	Rachel Wright
	Approved for release by:	Phillip Jellyman