Feeling the Heat: Predicting and Mitigating River Temperatures Under Climate Change

An open-ended mathematical modelling challenge to predict river thermal regimes under future climate scenarios and quantify the cooling effects of riparian shading and flow management.

1. Background According to the Horizons Regional Council *Climate Action Strategy [2]*, New Zealand's climate has already warmed by approximately 0.09°C per decade since 1909. The same strategy notes that in the Manawatū-Whanganui region, average air temperatures are projected to increase by up to 3.1°C by 2090. Furthermore, the *Manawatū-Whanganui Regional Climate Change Risk Assessment* [5] highlights that the region will experience a dramatic increase in "hot days" (exceeding 25°C), with areas like Whanganui and the Taumarunui hill country projected to see 50 to 60 more hot days per year by the end of the century under high-emission scenarios.

Hydrological Shifts: These climatic shifts will heavily impact river hydrology. As detailed in the *Climate Action Strategy [2]*, summer flows in the Manawatū River are projected to decrease by up to 14% by 2090, while annual rainfall is projected to increase by 15-20% in the north and decrease in the southeast by 20%.

Impacts on Freshwater Species and Algae: The combination of warming waters and reduced summer flows presents a severe threat to freshwater ecosystems. Rising water temperatures threaten aquatic species, which are already highly vulnerable to shifting climate conditions and loss of habitat. For example, studies show that water temperatures between 23°C and 25°C cause lethal thermal stress and increased mortality in trout [1].

Furthermore, these conditions are understood to favour the proliferation of toxic benthic cyanobacteria. The report *Climate change and toxic freshwater cyanobacteria in Aotearoa New Zealand* [4] indicates that *Microcoleus autumnalis* mats dramatically increase when water temperatures exceed 14°C and when river flows drop, reducing the frequency of the "flushing flows" that naturally scour the algae from the riverbed. These cyanobacteria produce neurotoxins that pose lethal risks to animals and significant health hazards to animals and humans.

2. Challenge Overview / Problem Specification This is a blue-skies project. We are not prescribing a specific methodology; instead, we are open to *any* mathematical, statistical, or computational approaches that the study group believes will be effective.

Your core challenge is to model and predict the thermal regimes of rivers under future climate change scenarios and determine how the effects of these temperature

increases can be mitigated. You may choose to explore deterministic energy-budget models that balance solar radiation and convective heat transfer (as discussed, for example, in *The thermal regime of rivers: a review [1]*), stochastic models utilising long-term and short-term air/water relationships, regression models, or entirely novel machine-learning, or other approaches.

Specifically, we ask the study group to explore:

- How much will our natural waterways warm under future air temperature and low-flow projections?
- To what extent can mitigations reduce the risk of extreme thermal events and keep waters below critical biological failure states? We specifically want you to investigate the cooling effects of:
    - **Riparian shading:** Blocking solar radiation, which *The thermal regime of rivers: a review* identifies as a critical factor in river heating.
    - **Flow management:** Augmenting river discharge. For example, what is the impact of restricting water takes during summer droughts.

3. Key Factors and Variables The models should consider a variety of environmental forcing factors and mitigation variables, which may include:

- Atmospheric and Meteorological Data
- Hydrological Dynamics
- Biological Thresholds
- Mitigation Levers

4. Data Available The team will be provided with:

- River temperature, flow, and gauging data.
- Riparian vegetation and stream shading estimates.
- Regional climate projections from the *Manawatū-Whanganui Regional Climate Change Risk Assessment*, including projected increases in "hot days" and potential evaporation deficits.
- Historical biological monitoring data regarding cyanobacterial coverage.

5. Desired Outcomes Because this is a blue-skies initiative, we are looking for innovative modelling frameworks which will help inform us of potential future management options.

6. Supporting References

1. Caissie, D. (2006). *The thermal regime of rivers: a review*. Freshwater Biology, 51, 1389–1406.
2. Horizons Regional Council. (2023). *Climate Action Strategy*.
3. Horizons Regional Council. (2023). *Manawatū-Whanganui Climate Change Action Plan 2023*.
4. Puddick, J., Kelly, L. T., & Wood, S. A. (2022). *Climate change and toxic freshwater cyanobacteria in Aotearoa New Zealand*. Prepared for the New Zealand Ministry of Health. Cawthron Institute Report No. 3765.
5. Tonkin & Taylor Ltd. (2021). *Manawatū-Whanganui Regional Climate Change Risk Assessment*. Prepared for Horizons Regional Council.