NOVEMBER 2022 (NEWSLETTER VI)

TE WHAKAHEKE O TE WAI

A quarterly newsletter for stakeholders of the TWOTW Research Programme

Karewarewa Stream at Bridge Pā in October 2020 (left) and January 2021 (right). The images show the intermittent nature of streamflow, for which the frequency of low flow and no flow periods are increasing. Photo: Tom Kitchin.

FROM THE PROGRAMME LEADERS

Catherine Moore and Uwe Morgenstern

Kia ora koutou and welcome to our November 2022 update for the TWOTW research programme. The project team have been busy continuing their technical work and also preparing publication papers and conference presentations.

In November we presented at the Australasian Environmental Isotope Conference (AEIC, Ballina) and the Australasian Groundwater Conference (AGC, Perth). This included a presentation at the AGC on the co-design of a groundwater model, where we explored the development of the Bridge Pa model, Hawke's Bay. The cover photo above shows differences in the intermittent streamflow of Karewarewa Stream. This week, the team are delivering a number of presentations at the New Zealand Hydrological Society Conference, which is being held in Dunedin from the 6 - 9th December. Details of these presentations are provided on Page 6.

Thank you for all your support for this project so far. We are looking forward to sharing and discussing more of this emerging science with you.

Ngā mihi, Cath and Uwe.

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WORKSTREAM FOCUS - STABLE ISOTOPES

The stable isotope tracer workstream will improve our ability to calculate mixing of waters (e.g., between local precipitation, groundwater, and river water), river water age, and recharge zones. Water age metrics for rivers can inform on water security (how much water is stored) and susceptibility of catchments to diffuse pollution.

For the last four years, NIWA scientists have been collecting water samples from rivers and precipitation across New Zealand to develop isoscapes (spatially explicit predictive models of isotopic values across landscapes). Water samples have been analysed at the NIWA Christchurch for deuterium (2H) and oxygen-18 (18O) content. Using a combination of a precipitation isoscape, river sampling, and modelling, we developed the first complete isoscapes of New Zealand's river network. An example of this is predictions for the Rakaia catchment, which is available on the NZRiverMaps site at https://shiny.niwa.co.nz/nzrivermaps/ (Figure 1).

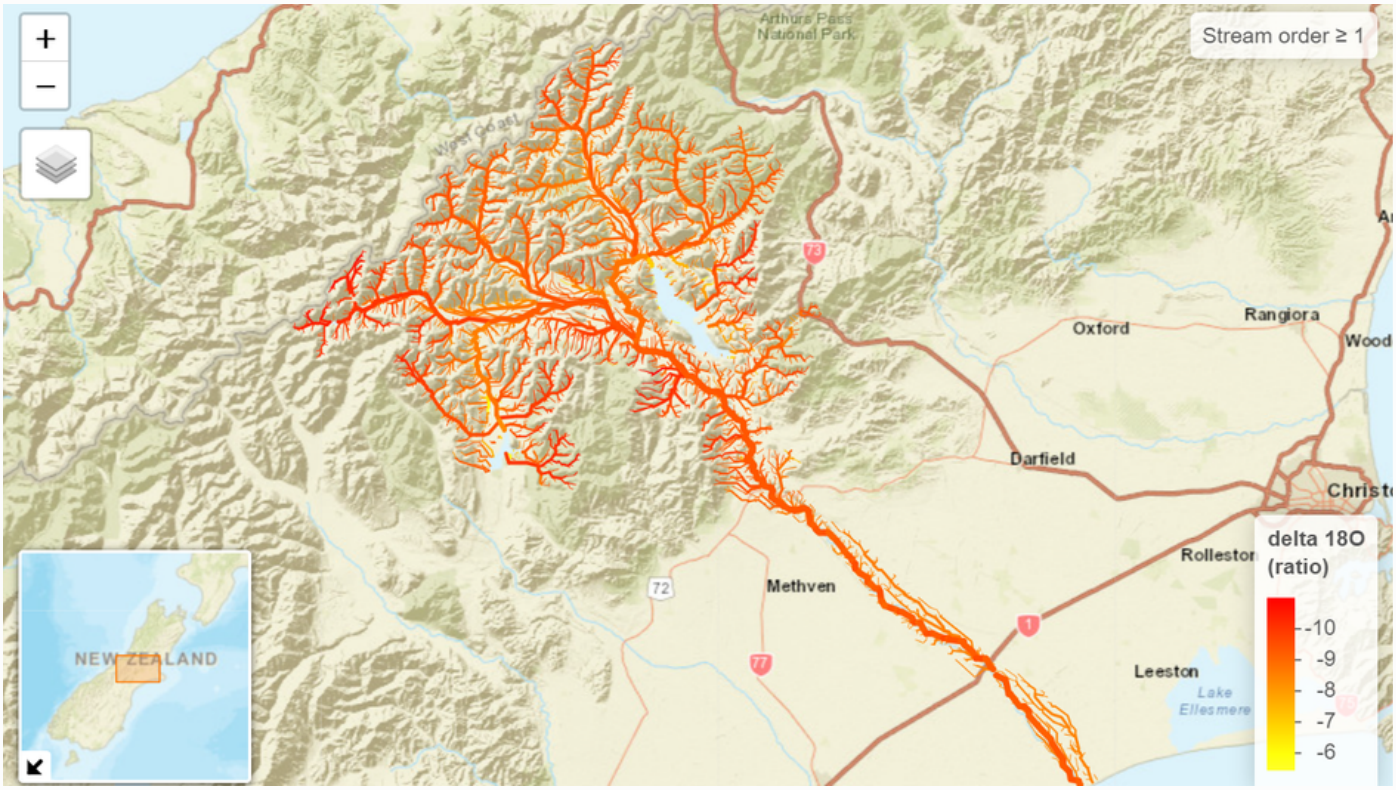

Figure 1. Oxygen isoscape of river water for the Rakaia catchment

In the last year, the work focus has shifted firmly to modelling spatial and temporal patterns of precipitation isotopes. A South Island high-elevation sampling network has been initiated to supplement existing precipitation isotope datasets (Figure 2). National sinusoidal precipitation isoscapes were developed to model how the annual, temperature-driven changes in precipitation isotopes vary across New Zealand. These isoscapes and river water isotope time series were used to calculate fractions of water < *c.* 3 months old in rivers across New Zealand (Figure 3). Comparison of these results with tritium and nutrient data collected from the same sites may allow us to understand how different age fractions of river water contribute to river water quality.

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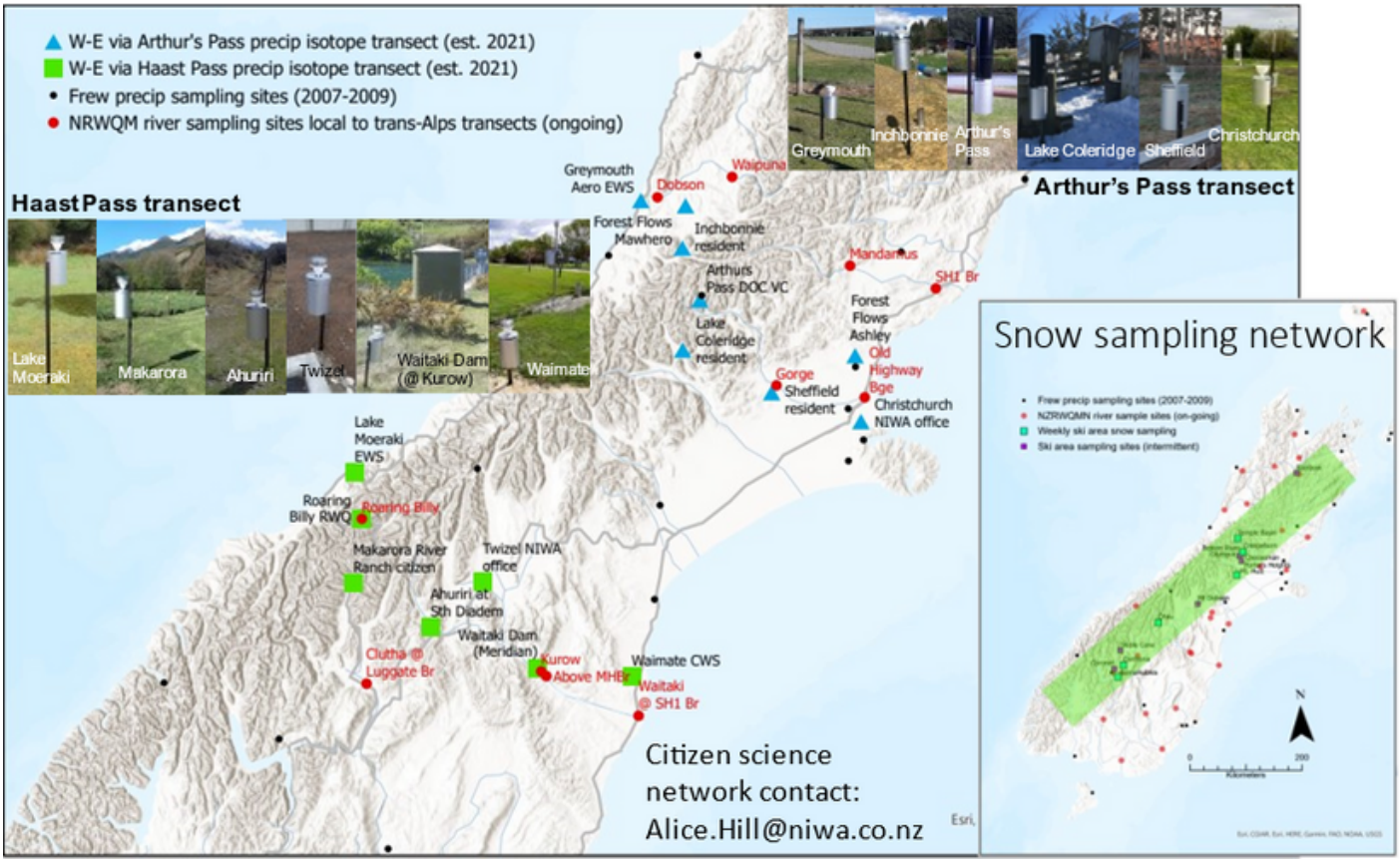

Figure 2. NIWA Trans-Southern Alps precipitation isotope data collection network.

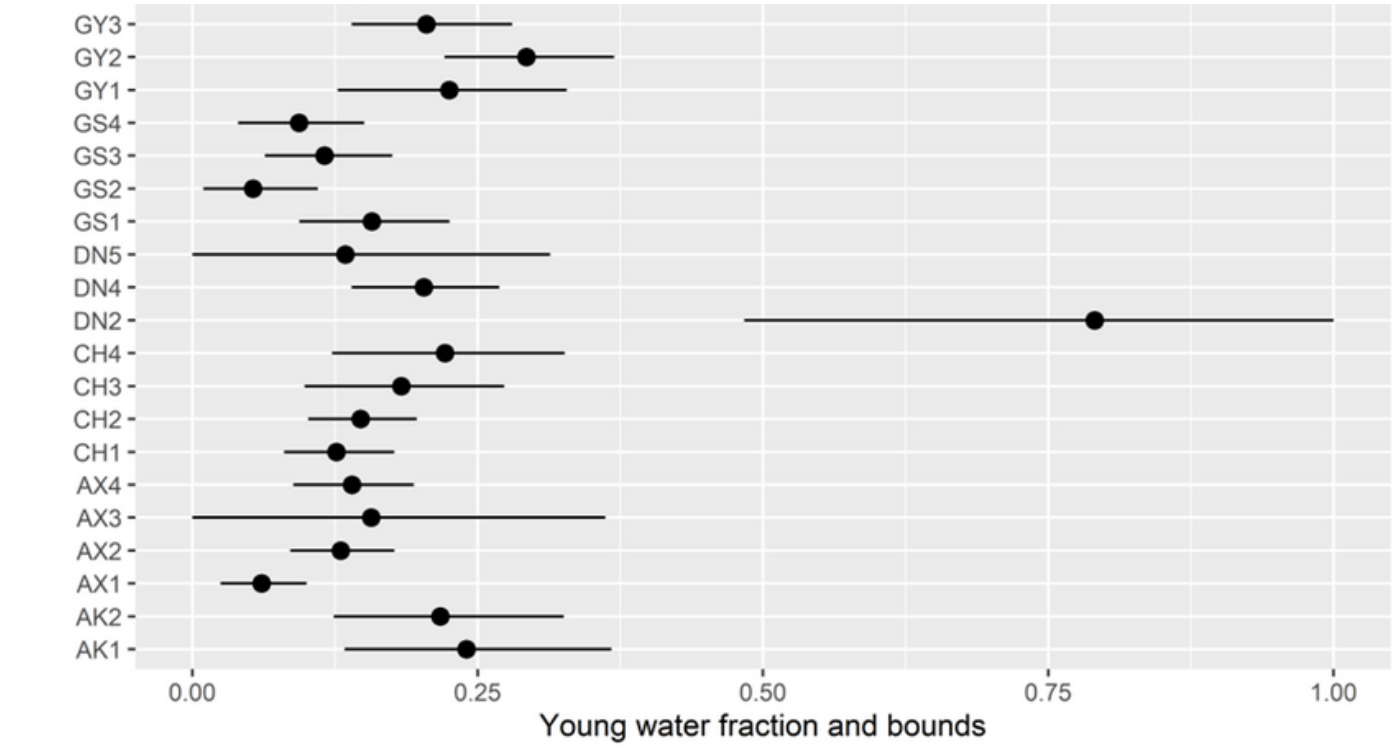

Figure 3. Young water fractions (the proportion of water < *c.* 3 months old) at a selection of sites across NIWA's National River Water Quality Network (NRWQN).

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WORKSTREAM UPDATES

National Modelling

The national scale groundwater model of New Zealand developed in TWOTW is intended to provide context for national scale water management decisions, as well as provide a consistent starting point for building regional or local scale models designed to answer more specific water management questions. Recent work has focused on developing the methodology to build regional and local scale models from the national scale model. This includes evaluation of boundary conditions, resolution of data requirements (e.g., stream networks, hydrogeology, recharge), and approaches for history matching to local data. These methods were developed using a model for the lower Wairau watershed and will be applied to other areas. Comparisons between this approach and a more refined modelling approach will be made to identify areas for improvement.

Meta-modelling

The science paper comparing two independent meta-modelling techniques to predict the groundwater age distributions from hydrochemistry parameters has been accepted by HESS as a preprint. The Symbolic Regression and Gradient Boosted Regression models are presented in the paper, which is available for discussion online: https://hess.copernicus.org/preprints/hess-2022-258/. To increase the number of training data and therefore the robustness of the metamodels, the meta-modelling team is now looking into using hydrophysical data to determine groundwater age.

Source Protection Zone (SPZ)

Our numerical experiments continue. Using the West Melton case study, we examine whether vertical anisotropy or porosity proxies can be used in simple models, to match the outputs of complex and computationally demanding stochastic simulations. We also investigate how backward particle tracking, which is the most commonly used approach for numerical delineation of SPZs, compares with the more robust forward particle tracking, and what assumptions on particle termination need to be made to ensure a reasonable agreement between the two methods

National tracer survey

The recent focus of the national tracer survey has been to undertake Northland regional sampling, which has been almost completed during October. The focus of sampling campaigns is now shifting to the east coast. In Gisborne / Tairawhiti sampling will include natural spring discharges from the groundwater systems, and in the Heretaunga Plains sampling will be used to test:

- if the Tukituki River contributes water to the Heretaunga Plain aquifer or if the water lost from the river only flows via preferential flow paths and emerges as springs into the Karamu Stream; and
- if the Moteo Valley contributes recharge to the main Heretaunga Plains aquifer.

Currently the workstream is working with Environment Canterbury, Otago Regional Council, and Taranaki District Council sampling over the coming summer.

Vision Mātauranga

Recently, Amber has been exploring Māori Land Court Blake Notebooks for observations and mātauranga relating to wai in the Heretaunga Plains. She has a number of outputs in progress including a presentation at NZHS (Dunedin) and writing up the research into publication format.

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INTRODUCING OUR TEAM

We would like to introduce the following key scientists who are working on the isotope workstream within TWOTW. The team is predominantly composed of staff from NIWA Christchurch and more recently, Paul, who is based at GNS Science, Wairakei.

Jing Yang

Jing is a hydrologist at NIWA, with an over-15-year experience in hydrologic engineering and academic research. He is skilled in surface and groundwater modelling, floods and droughts, water resource management, impact of climate change on surface and groundwater resources, and sensitivity and uncertainty analysis to support surface and groundwater resources managements. Within the Te Whakaheke o Te Wai Programme, he works on the surface water modelling and water source separation based on the water quality and flow data. Before joining NIWA, Jing had a range of international experience working in China, Europe, Canada and Singapore.

Bruce Dudley

Bruce is a biogeochemist at NIWA. His primary research interests are abiotic controls of primary production and movement of water and nutrients through ecosystems. He specialises in examining pathways of water and nutrient fluxes using stable isotopes. Within the Te Whakaheke o Te Wai Programme Bruce manages stable isotope analysis, conducts national isoscape development, and calculations of river water age metrics across the National River Water Quality Network sites. He has worked in the hydrology and hydraulics groups at NIWA Christchurch since 2014. Prior to this Bruce completed a post-doctoral fellowship as a biogeochemist, with the University of Hawaii and the United States Forest Service

Paul Oluwunmi

Paul joined the groundwater modelling team at GNS Science in May 2022. He has experience in coupled processes, including flow, thermal, geomechanical, geochemical, and geophysical. Paul is currently applying a Bayesian chemistry-assisted hydrograph separation method (BACH and BACH2) to NIWA monitored sites where there are concurrent records of flow, phosphorus, and nitrogen concentrations to determine the contribution to stream flow from a combination of three separated flow paths (i) fast (event-response near-surface flow), (ii) medium (seasonal shallow local groundwater flow), and (iii) slow (persistent deeper regional groundwater flow).

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CONFERENCE PRESENTATIONS

The following papers have been submitted and accepted to the NZ Hydrological Society and NZ Meterological Society Joint Conference. The conference is being held in Dunedin from the 6th - 9th December, 2022 and the theme is '*Water: our taonga in an ever changing world*'.

- Hemmings, B., Moore, C., Kitlasten, W., Chambers, L., and Scadden, P., Improving stochastic modelling workflow visualisation, interrogation, and interaction.
- Kenny, A., Sarris, T., Scott, D., Moore, C., Determining Source Protection Zones for Heterogeneous Aquifers: Insights from Comparing Complex & Simple Methods.
- Kitlasten W., Taves, M., Zammit, C., and Yang J., Modelling groundwater and surface water interactions in the New Zealand water model (NZWAM).
- Kitlasten, W., Moore, C., Hemmings, B., and Taves, M., Considerations for National Scale Model of Groundwater Age.
- Moore, C., Aranui, A., Taves, M., Hemmings, B., Morgenstern, U., Mercier, O., Doherty, J., Black, M., Tiuka, N., Smith, S., and Apatu, M., Model-based processing of measured and historical stream behaviour; seeking culturally meaningful environmental restoration.
- Moreau, M., Morgenstern, U., Van der Raaij, R., Murphy, P., and Ferry, J., Groundwater dynamics and hydrochemical evolution as inferred from Gisborne's Regional Age and Chemistry data.
- Morgenstern, U., Moreau, M., Coble, M.A., Rogers, K.M., Johnson, K., and Buckthought L., Groundwater and surface water processes and flow dynamics in the Pukekohe - Bombay basaltic aquifers.
- Morgenstern U., and Davidson P., Groundwater tracers for understanding water and nitrate flow through Te Hoiere / Pelorus catchment.

The 15th Australasian Environmental Isotope Conference (AEIC) was held in Ballina, Gold Coast, from 14 - 16th November, 2022. The following abstract was submitted:

- Morgenstern, U., and Davidson, P., From Rain through River Catchment to Aquifer: The Flow of Water through the Wairau Hydrologic System.

In addition, three abstracts linked to work within TWOTW have been submitted to the Australasian Groundwater Conference which directly follows on from the AEIC. The conference had a theme of '*Science, Resilience, and Adaptation*' and was held in Perth from the 21 - 23rd November, 2022:

- Hemmings, B., Moore, C., Kitlasten, W., Chambers, L., and Scadden, P., Improving stochastic modelling workflow visualisation, interrogation, and interaction.
- Morgenstern, U., and Moore, C., Groundwater Recharge and Flow Dynamics in the Heretaunga Plains, Hawkes Bay, New Zealand.
- Moore, C., Aranui, A., Taves, M., Hemmings, B., Morgenstern, U., and Mercier, O., Co-design of a groundwater model: a case study.

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TWOTW PROGRAMME SUMMARY

Te Whakaheke o Te Wai (TWOTW) is a five-year research programme funded by MBIE's Endeavour Fund and led by GNS Science. Multiple national and international organisations and stakeholders are involved in the collaboration. Primary collaborators of the research programme include NIWA, ESR, Te Tai Whenua O Heretaunga, Victoria University of Wellington, and Watermark Numerical Computing. Hawke's Bay Regional Council support the major case study area, the Heretaunga Plains. Other regional councils and organisations also contribute to the research project, including with co-funding.

The TWOTW programme aims to better support water management based on improved understanding and integration of flow sources, pathways, water travel time, and cultural knowledge and values in New Zealand. The research is underpinned by the concept and defining of 'Te Whakaheke o Te Wai' of groundwater throughout the main catchments and aquifers in New Zealand. The 'Te Whakaheke o Te Wai' of groundwater - our largest freshwater resource - is largely unknown, yet stakeholders recognise that this knowledge is urgently needed to protect and sustainably manage groundwater and the rivers and streams it feeds. Outputs from this research are to provide decision-makers with much needed knowledge for improved water management at national, catchment, and local scales. Outputs from the research will be publicly available and benefit people and institutions involved in water management.

The programme is currently developing the world's first nationally continuous maps of groundwater age, origin and flow paths. A technical foundation of the research project is the development of new modelling technologies. This project builds on the current knowledge and implementation of data assimilation and uncertainty quantification commonly expected and often required in modelling projects. This research is evolving modelling capability from simply understanding uncertainty (which is now generally accepted in modelling), to the design of novel models with an ability to reduce that uncertainty. This includes combining mātauranga Māori and mōhiotanga Māori with aquifer models to reduce this uncertainty. This is a unique combination of western science and indigenous knowledge that demonstrates the importance of combining the two knowledge systems. New stochastic approaches for source protection zone modelling (SPZ) are also being developed.

Key researchers

GNS Science: *Catherine Moore, Uwe Morgenstern, Brioch Hemmings, Conny Tschritter, Sapthala Karalliyadda, Wes Kitlasten, Mike Taves, Paul Oluwunmi, Susana Guzman, Lee Chambers, Magali Moreau, Stewart Cameron*

VUW: *Ocean Mercier, Amber Aranui*

ESR: *David Scott, Murray Close, Theo Sarris, Alannah Kenny*

NIWA: *Bruce Dudley, Jing Yang, Chris Daughney*

Students: *Tara Forstner, Willow Milligan, Oscar Arnold, Alyssa Thomas*