FUTURE-PROOFING GROUNDWATER SYSTEMS

Buffering climate change effects on water availability and quality

Earth Sciences New Zealand

Uwe Morgenstern (Principal and Lead Scientist, Isotope and Tritium Lab) sampling.

FROM THE PROGRAMME LEADERS

Catherine Moore and Uwe Morgenstern

Kia ora koutou,

Welcome to our first update on the Future Proofing Groundwater research programme. In this issue we focus on providing an overview of the programme, plus provide a brief update of progress in each of the five main parallel and interwoven components. We also share a snapshot of a series of hui held late November 2025 in Northland. We have ramped up our sampling programme, starting in the Hauraki Plains and Heretaunga Plains. We use a novel analysis of noble gas concentrations in groundwater to deduce excess nitrogen, which enables the identification of actual nitrate removal processes occurring along flow paths. This is critical information for assessing how best to manage land use so that water quality impacts are avoided. Our national groundwater model is currently being history matched to transient data. It is focussing on records of low groundwater levels and stream flows across the country, providing a tool that focusses on simulating our integrated freshwater system under drought stress. It will then be used to assess how the frequency and duration of these low flow and low groundwater level events may change under climate projections. Later in the programme the same model will be repurposed to explore the impact of land-use change on nitrate loads in freshwater, making use of the new information from the excess nitrate sampling programme. We have also started to focus on local scale decision making. At this scale adaptation to climate changes must be tailored to local hydrological conditions and the values and aspirations of those who live in those areas. In mapping future decision pathways, local scale decision making also must accommodate the significant uncertainty associated with future climate projections. At this scale, social and hydrological tools are interwoven so that cultural and economic impacts are understood and inform decision making.

Nga mihi, Cath and Uwe

LATEST NEWS

The Future Proofing Groundwater team recently spent a week in the Far North, as part of the establishment of place-based case studies with hapū and iwi. The visit involved a series of hui at marae and public venues to introduce the project's objectives and, crucially, to listen to the questions and clarifications from local whānau. Groundwater resources in the Far North are under growing pressure from competing demands from multiple current and potential users, alongside the need to maintain long-term water security, and ensure the sustainability and cultural integrity of the resource. The Adaptation Pathways workstream will bring together local understanding and priorities for groundwater, with the latest modelling of future conditions. This first step was critical to start with listening to, and understanding the social, environmental, political and cultural context of the region.

The team heard from a range of kaitiaki, water-users, as well as those concerned about the future of the resource. These insights are now being used to design further engagement, in preparation for additional hui and pathways planning processes. These case studies will eventually provide a template for water resilience that can be shared through hui and workshops across Aotearoa. Adaptation pathways are not rigid plans - they are a flexible, long-term approach to managing climate-related risks and opportunities. In a world of environmental uncertainty, this method allows us to identify various actions that can be taken over time, ensuring that communities are never 'locked into' a path that no longer serves them. Our time in the Far North was beginning the process of co-design. By working alongside hapū and iwi, we are exploring the unique values, economic drivers, and aspirations that define the region's relationship with groundwater. We extend our sincere thanks to our hosts for their manaakitanga and for the kōrero that will guide this roadmap toward a sustainable future for our freshwater systems.

Team photo outside the wharekai at Waimanoni marae.

INTRODUCING OUR RESEARCH

Programme overview (Catherine Moore and Uwe Morgenstern)

Future-proofing Groundwater Systems

Buffering climate change effects on water availability and quality

Earth Sciences New Zealand (ESNZ) is building our understanding of the inner workings of Aotearoa's groundwater systems, mapping their vulnerability to future climate and land-use pressures, and developing adaptive planning approaches for resilient groundwater management. The availability and quality of freshwater in Aotearoa New Zealand is declining, and climate change will bring significant additional pressures to our freshwater resources.

Overview

Groundwater sustains lives and livelihoods. It replenishes the flows of Aotearoa's rivers and streams, makes up much of our drinking water supply, and accounts for over 80% of water used for irrigation in our horticulture and agriculture industries. Yet we currently have few tools to effectively manage it.

Aotearoa's groundwater is declining in quantity and quality at the same time as demand for this vital resource increases — a problem that is projected to worsen due to climate change. To protect our groundwater resources and adapt to changes in climate and land use, we urgently need to better understand groundwater systems and develop new strategies to manage and protect them.

The Future-proofing Groundwater Systems research programme brings together groundwater modellers, isotope hydrologists, complex-system and policy scientists, researchers, and mātauranga Māori experts. This multidisciplinary team will develop an agile groundwater management framework based on an enhanced understanding of:

- Aquifer structure and storage parameters
- Groundwater source, age, recharge, and flow rates
- Nitrate assimilation capacity at catchment levels

Research aims

- Identify where groundwater systems can buffer drought impacts.
- Identify where groundwater is most able to buffer nitrate load.
- Simulate the effectiveness of management interventions at decision-relevant scales.
- Deliver simulator-based data-processing supporting adaptation decisions that characterise trade-offs and synergies, to define optimal management pathways.
- Implement dynamic adaption pathways for freshwater resources with multiple highly contested goals and complex physical environments.

INTRODUCING OUR RESEARCH

Workstream One (Zara Rawlinson/Rogier Westerhoff)

Analysing the fingerprint of isotopes formed by cosmic rays to understand aquifer storage capacity and drought resilience.

- Workstream One is working in tandem with Workstreams Three and Four to provide inputs to groundwater flow modelling at both the national and case study scales. Different datasets are being explored to provide refined information to the models. After they've been run, groundwater flow model outputs will be processed to generate national drought index maps.
- Refined information includes aspects such as rainfall recharge model estimates, estimates of groundwater contributions in streams, and aquifer structural information.
- One dataset being explored is derived from an innovative tracer technique to identify where the groundwater has come from and how long it has been underground. One of the tracers used is Tritium, a radioactive isotope of hydrogen produced in the atmosphere by nuclear reactions between cosmic rays and atmospheric gases. After Tritium combines with oxygen forming water molecules, it becomes part of the water cycle. As part of the rainwater, it enters groundwater systems and there it can be used as a 'radioactive clock'. When the rainwater infiltrates into the ground and becomes separated from the atmosphere, the clock starts to tick, with the Tritium concentration decreasing. This decrease can be measured and the age of the groundwater calculated.
- The groundwater age data is used to provide information about the dynamics of groundwater flow, including recharge rates, and volumes of the dynamic storage of the aquifers that feed our rivers, along with data from airborne electromagnetic surveying.

Workstream Two (Uwe Morgenstern)

Identifying aquifer resilience to nitrate contamination

- In a world-first, the team will measure groundwater denitrification at the catchment scale, using ESNZ new state-of-the-art noble gas facility. Nitrate (NO_3) is a chemical compound that occurs naturally, and is required for plant growth, but the use of fertilisers and waste from animals adds to the amount of nitrate in the environment. When there is too much nitrate it can leach from the soil and contaminate our ground- and surface water.
- Microbial denitrification is a naturally occurring process, which under the right conditions can reduce nitrate (NO_3) in groundwater into inert harmless N_2 gas. This 'excess-nitrogen' accumulates in the groundwater along its flow path. At springs or wells where the groundwater discharges the amount of excess-nitrogen can be calculated from noble gas concentrations. Noble gas analysis allows the team to calculate the amount of 'intrinsic' nitrogen in the groundwater (atmospheric N_2 that has been dissolved in rainwater and infiltrated the groundwater system) to then quantify how much denitrification has occurred in the groundwater system.
- Through this improved understanding of where denitrification is taking place, and the conditions under which denitrification occurs, the programme will identify strategies to enhance mitigation of excess nitrate loads.

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Workstream Three (Wes Kitlasten)

Simulating freshwater response to climate and land-use change

- A national groundwater model will be extended to extract information from available and new data, including groundwater isotope and geophysical data, to understand how groundwater vulnerability to land use and climate change impacts vary spatially.
- Model simulation outputs will show how water availability and water demand relationships vary across New Zealand currently, and how they will change given climate projections. This will support the exploration of climate change implications for freshwater availability for communities, the environment and the economy.
- The national groundwater model is tightly coupled with a spatially explicit recharge routing model and is being history matched to satellite derived estimates of actual evapotranspiration and estimates of groundwater demand (i.e., pumping). This approach tracks all water through the system and provides a better representation of the spatial distribution of recharge along the mountain fronts.
- Simulation outputs will also map where land use presents a higher and a lower risk of nitrate contamination of freshwater systems. This will harness the information from the new noble gas analyses, to map where denitrification is occurring. This will support explorations of how changing land use at a location would increase or decrease impacts on freshwater.

Workstream Four (Catherine Moore)

Innovative modelling to guide adaptive management strategies

- Researchers will develop tools to guide adaptive management decision making processes for communities. These tools are designed to be used iteratively, in contexts where there is significant uncertainty, and where decision relevant information is increasing over time as early warning (sentinel) monitoring data is collected.
- These modelling tools will be designed to be computationally efficient, and able to navigate water allocation and land use decision trade-offs and synergies across a range of values and aspirations in a community. They will be capable of identifying the most reliable early warning monitoring systems, which will be used to determine whether a change to the adaptation management pathway is required. The tools will rapidly process new monitoring data as soon as it becomes available, to assess if freshwater responses to management are as expected, or whether the management pathway must be reconsidered.

INTRODUCING OUR RESEARCH

Workstream Five (Nick Cradock-Henry)

Developing adaptation pathways for freshwater

- Adaptation pathways provide a flexible, long-term framework for managing climate-related risks and opportunities. Rather than relying on a single, rigid plan, this method identifies a suite of potential actions that can be implemented over time as conditions change and new information becomes available.
- This approach avoids “locking-in” infrastructure or policies. By mapping solutions over a long-term horizon, we can prevent investing in strategies that may become ineffective or redundant under future climate scenarios and ensure that communities and decision-makers remain agile.
- Our team is working directly alongside iwi and hapū in Hawke’s Bay and Northland to understand their specific values and aspirations. This collaboration ensures that the pathways are grounded in local places; the economic drivers, cultural values, and existing decision-making processes of the people who live and work within these catchments.
- We are co-designing these pathways by weaving together new scientific knowledge of groundwater systems with place-based insights and mātauranga Māori. These integrated plans will provide practical, long-term guidance for enhancing drought resilience and managing nitrate loads in freshwater systems across various management scales.
- While rooted in regional case studies, these pathways are designed for broad application across Aotearoa. The findings and methodologies will be shared through stakeholder engagement, public outreach, workshops, and hui to support freshwater management efforts nationwide.

Collaborators and funding

Collaborators: The project is led by Earth Sciences New Zealand, with collaborators Lincoln Agritech, Aqualinc, Land Water People, Scarlatti, Te Herenga Waka – Victoria University of Wellington, University of Otago, and a range of international collaborators.

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