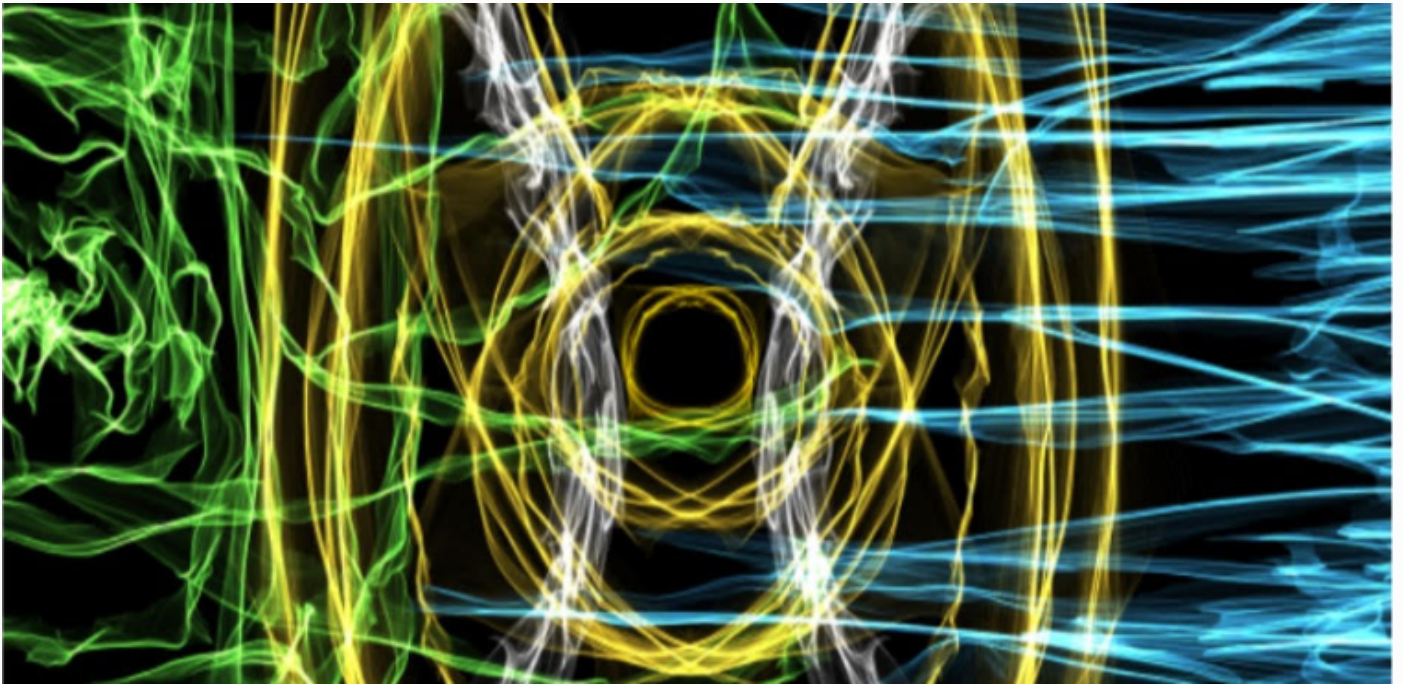


TE WHAKAHEKE O TE WAI

A quarterly newsletter for stakeholders of the TWOTW Research Programme



Artistic offering produced using Weavesilk, showing how the wāhi ngaro model could be applied. The central grey brackets represent the interface between two worldviews. Different knowledge/worldviews are represented as the green and blue domains. The green and blue tendrils extending past the brackets represent cultural expertise and collaborative efforts. Collaboration is represented when the tendrils entwine. New knowledge is represented by the concentric gold circles emanating from the potential space. (Arnold, 2023). Additional information is provided by Oscar in the summary of his student project, starting on Page 3 of this newsletter.

FROM THE PROGRAMME LEADERS

Catherine Moore and Uwe Morgenstern

Kia ora koutou,

Welcome to our April 2024 update on the TWOTW research programme. In this issue we focus on our students and present a summary of the excellent research they have undertaken. We also share a snapshot of some of the meta modelling results later in this newsletter. Our meta modelling has been extended to three regions (Heretaunga Plains, Wairau Plains and the Manawatu-Wanganui (Horizons)). Initial results are promising in terms of being able to extrapolate groundwater age samples to provide estimates of general groundwater age distributions nationwide, using mappable variates. The aim is to roll out the meta modelling approach to all sampled areas.

FROM THE PROGRAMME LEADERS (CONTINUED)

Catherine Moore and Uwe Morgenstern

A number of parallel efforts are also underway, and will be the subject of next newsletters. These include the push to complete the national groundwater age sampling campaign. A series of reports using this data are currently being completed and summarise regional groundwater system conceptualisations across the country. Final reports currently near completion are focussed on the Gisborne, Tasman, Taranaki, Marlborough and Bay of Plenty regions.

A novel catchment biography is also near completion. This biography incorporates mātauranga that sits with the hapu of Bridge Pā and wider iwi in Heretaunga, and information from claims hearings, survey plans and geology, geomorphology, climate, groundwater, surface water and soil data. The biography provides insights into the past stresses and states of the groundwater system from pre-European and pre-human periods, through periods of forest clearing, land drainage, and border-dyke irrigation, through to recent rapid increases in groundwater usage in the catchment. This work is represented in a groundwater numerical model (also near completion) which has the goal of providing a numerical voice for community concerns, and a tool to inform restoration discussions.

The national scale numerical database model, accompanied by rapid model build tools is near completion. This model-tool combination is intended to support the build of decision-scale focussed models rapidly and cost effectively where they are needed. Two regional numerical models are also near completion, the Heretaunga groundwater age model and the Wairau groundwater age model. Exciting new groundwater modelling methodologies are being developed and tested on these decision-scale models to enhance extraction of prediction-relevant information in available data, and reduce the uncertainty associated with estimated predictions.

Ngā mihi,
Cath and Uwe.

FOCUS - STUDENT THESES

Wāhi Ngaro: an offering to cross-cultural management of groundwater (Oscar Arnold).

Kia ora, ko Oscar toku ingoa. I've grown up cross-culturally and I'm a tangata tiriti researcher with a BSc in environmental studies and a minor in Māori Studies. For my Honours thesis, I researched the cross-cultural management of groundwater with a specific focus on Te Ao Māori. I wrote my thesis in three sections: Firstly a socio-political overview, secondly an analysis of current cross-cultural practices and lastly, an exploration of the Māori philosophy of the Wāhi ngaro, a multi-dimensional and pregnant liminal space, as an offering to improve cross-cultural groundwater management. Each section will be briefly summarised.

Firstly the socio-political context. Immediately, it was important to address that the cross-cultural foundations of Te Tiriti were omitted for 135 years after signing, until 1975 - during this time significant decision-making infrastructure was developed without Māori inclusion. Following on, colonisation and widespread land use changes have had enormous and tentacular impacts on the environment and waters of Aotearoa NZ. Additionally, decision-making authority over water remains disputed, as illustrated by the unresolved WAI#2357 and #2358 Waitangi tribunal freshwater and geothermal reports. Māori are claiming authority as per their status as tangata whenua, and as per the rangatiratanga enshrined to Māori in Article 2. On the other hand, the Crown is arguing that no one owns water while acting as if they do by selling off resource consents and managing regional infrastructure. The work to navigate these socio-political tensions remains ongoing. The Coleridge Dilemma has been used to describe the conflicting interests in Aotearoa NZ - it is not the amount of water that is the issue, it is the competing management priorities. The privileging of economic interests above all else, including the health of the people and the environment, is outpacing sustainable supply, jeopardising the longevity of groundwater freshwater reserves. If our collective management tools are struggling already then these challenges will crescendo with the consequences of climate change.

The second section was an analysis of 5 indigenous cross-cultural models: Two-eyed seeing, Te Awa Whiria, He Waka Taurua, The Mauri-o-meter, and the Mauri compass. Of all of these models, Two-eyed seeing is the only international model, the rest are developed from a Māori worldview. The key takeaways from each model will briefly be outlined. Two eyed seeing adds a depth of perspective that would be blind to each worldview individually. Te Awa Whiria represents both worldviews as rivers with their own upstream topography, symbolic of the unique development of each worldview. He Waka Taurua, is a great way to inventory cross-cultural tools, strategies and collaborative approaches. The Mauri-o-meter is an integer metric to assess the Mauri (vitality, life, energy density) of an ecosystem. Lastly, The Mauri compass is a concise cross-cultural representation of socio-environmental complexity. The strengths of all of these models was drawn on to inspire the development of the Wāhi ngaro as a cross-cultural tool.

FOCUS - STUDENT THESES (CONTINUED)

The Wāhi ngaro is a versatile, profound and layered concept within Te Ao Māori, and each iwi and hapu will have their own definition, relationship and expression. The literature reflects that the Wāhi ngaro has relevance to an interface space, a lost place, an unknown/unseen realm, a pregnant potential and womb space metaphor, linking to philosophy and cosmology. The Wāhi ngaro resonates with groundwater as an unseen, interface space of enormous potential that needs to be better understood. The last section of my thesis was offering the Wāhi ngaro as a cross-cultural platform. Drawing on the strengths of all the models, I offered the Wāhi ngaro as a 4-tier scaling water management model. The most macro-scale is a conceptual space to facilitate cross-cultural conversation and collaboration, linking to the two-eyed seeing and Waka Taurua models. Zoom in to reveal a national map, analogous to a weather map that triages the national and regional hydro-geological contexts with the mauri-o-meter integer metric. Zoom in further to see each locality represented in more detail through the Mauri compass at the most micro scale. The Wāhi ngaro was chosen because of its capacity to accommodate myriad complexities in one framework - a framework with an emphasis on partnership and potential. Should the Wāhi ngaro be developed any further as a cross-cultural framework, it needs to be lead by Māori.

Groundwater is understood using both western science and mātauranga Māori logics. If we can learn to see eye to eye, and then learn to see through both eyes, we have the potential to learn more than either worldview could do in isolation. The insights from both cultures could be enriched and extended if we can increase our cross-cultural fluencies. Time will tell. With climate change we need to act quickly, we need all hands on deck and we need all tools available. Thank you for the opportunity to do this research, I feel I learnt a lot.

Arnold, O., 2023. Wāhi Ngaro: an offering to cross-cultural management of groundwater. Bachelor of Arts (Honours) Thesis, Te Herenga Waka - Victoria University of Wellington. 58 p.



Since submitting my thesis, I'm engaged with He Waka Kuaka to work on publishing it. I've also had the enormous privilege of volunteering in South Africa/Botswana in the rescue and relocation of two Lionesses in November/December 2023. Since concluding my time in Africa, I've also been travelling to Brisbane and throughout New Zealand. My fiancée and I have been travelling to plan our wedding, catch up with family and go on some writing retreats to develop some seedling projects. I've been involved in developing physical theatre workshops that choreographically represent some climate dynamics like the El Niño Southern Oscillation. I look forward to studying climate and cross-cultural dynamics for the foreseeable future.

FOCUS - STUDENT THESES (CONTINUED)

Ngā Rangatira Mō Apōpō. Rangatahi aspirations for Pukekauri dam in Patuharakeke rohe: an educational wānanga for youth engagement and visioning (Alyssa Thomas).

The research sought to support the expression of iwi interests, engaging with the youth of Patuharakeke hapū to hear their aspirations for the sustainability of our local taiao. Specifically, the case study area is Pukekauri Dam, a valued water source in the area that is currently in the midst of co-governance negotiations.

The wānanga was a three-day, two-night event at Takahiwai marae in Northland, with a target audience of Patuharakeke hapū rangatahi aged 14-18. The kaupapa navigated marae tikanga, the local forest and water sources, group discussions, social time and environmental restoration. The research aimed to integrate a harmonious balance of Mātauranga Māori and Western science throughout the wānanga. A primary finding of the research determined that whakawhanaungatanga (building relationships) was most valued by the rangatahi. This recurring theme demonstrated how much they enjoyed being around their cousins and whānau. This finding supports place-based education and tikanga Māori for rangatahi engagement. Rangatahi (youth) voices are important to Patuharakeke hapū because they are part of the succession planning, where our rangatahi are the Leaders of Tomorrow (Ngā Rangatira Mō Apōpō).

Thomas, A., 2023. Ngā Rangatira Mō Apōpō. Rangatahi aspirations for Pukekauri dam in Patuharakeke rohe: an educational wānanga for youth engagement and visioning. Master of Indigenous Studies, Te Herenga Waka - Victoria University of Wellington. 111_p.



Alyssa (above) and taitamariki at Pukekauri (right).



FOCUS - STUDENT THESES (CONTINUED)

Cultural Health Monitoring in the Tākaka Catchment (Willow Milligan).

Kia ora koutou! Over the last two years I have been undertaking a Masters of Arts in Māori Studies at Te Kawa a Māui, Victoria Univeristy, Wellington. Throughout this time I have been living and researching in Mohua (Golden Bay), exploring opportunities for cultural health monitoring of the Tākaka catchment. The Southern half of this catchment recharges the Wharepapa Arthur Marble Aquifer which distributes wai ora out through Te Waikoropupū and ocean vents in the local bay, Te Tai Tapu. This is the rohe of Ngāti Tama, Te Ātiawa and Ngāti Rārua and the puna is a significant wāhi tapu for all. Notably Te Waikoropupū and the adjoining water bodies have recently been granted a Water Conservation Order for their protection. A key requirement of the Order was for Manawhenua to develop and implement a cultural health monitoring programme for the Tākaka catchment.

As a researcher I have been supporting this need by firstly exploring the historical context of the catchment, how it has changed over time and what the key relational changes were which impacted on its mauri. This has involved incorporating different data from hydrological reports, archival texts, pūrākau, kōrero tuku iho and ecological reports for the catchment. Through working alongside Manawhenua and other knowledge holders in the area I have then developed an analysis of the key interface zones within the recharge area that could be used for cultural health monitoring purposes. Building on the historical context and knowledge about key interface zones for wai moving ki uta ki tai (mountains to sea), the research has culminated in a list of considerations for a cultural health monitoring methodology for the Tākaka catchment. This will eventually be utilised by Manawhenua in Mohua to support the implementation of a cultural health monitoring programme for the whole catchment, ki uta ki tai. The aspiration is that this programme will strengthen their understanding of the flows and encounters of wai through their catchment and support them to make informed, strategic and resourced decisions as kaitiaki of the rohe.



Willow and his research assistant.

I am very grateful for the support of Te Whakaheke o Te Wai, GNS, Te Herenga Waka and my amazing supervisors Dr. Ocean Mercier and Dr. Lorena Gibson. This has been such a wonderful learning experience.

Mauri ora.

FOCUS - STUDENT THESES (CONTINUED)

**PhD Candidate, Waterways Centre for Freshwater Management, University of Canterbury
Te Whare Wānanga o Waitaha (Tara Forstner).**

This research is focused on investigating 'hindcasting' modelling methods for assessing the pre-European conditions. The site is located in Pakipaki, Hawkes Bay, and centred around concerns of decreased spring flow at Te Puna a Hinetemoa, a culturally important spring. The objectives are to (a) determine the original state of spring flow, (b) understand the factors that influenced the decrease in spring flow and the historical evolution of hydrologic changes, and (c) explore rehabilitation strategies. This research examines approaches to hindcasting data assimilation, uncertainty quantification, and applications for groundwater rehabilitation.

Initial results from a global literature review of hindcasting models, highlight the scarcity of groundwater research which encompass historical conditions particularly prior to instrumental records. We propose a novel way to classify types of hindcasting methods and discuss opportunities to address future research within the domain of groundwater nexus systems (ie. human, ecological, cultural) using hindcasting methods.

Currently, field monitoring is underway, with both local water level monitoring from two newly installed shallow piezometers, and water quality sampling in the Upper Awanui catchment area, which is providing new data on the margin of the Heretaunga Plains. While onsite in Oct 2023, ākonga from the Pakipaki School volunteered to help us with some of our field monitoring (see below). Looking forward, we aim to finalize the last round of field sampling in May 2024. This data will be assimilated into the hindcasted groundwater model.

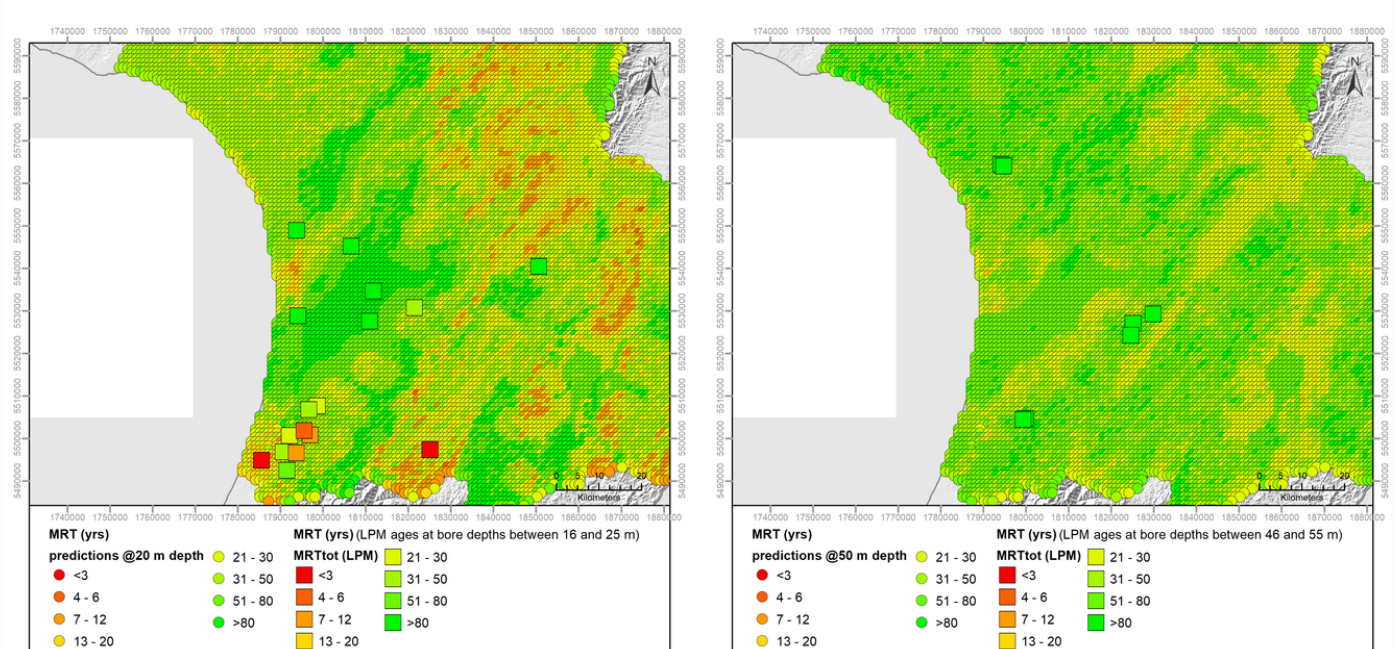


Tara and her field assistants collecting water field measurements from an artesian well in Pakipaki.

META MODELLING UPDATE

In the meta modelling workstream, we are currently trialling how to predict groundwater age across different areas in New Zealand. Groundwater age refers to the length of time since water infiltrated into an aquifer and is an important indicator for aquifer vulnerability, contaminant transport, and water resource management.

The map on the left (below) shows preliminary results in the Manawatū-Whanganui region at a depth of 20 m. Mean Residence Time (MRT) in the map is used synonymously with groundwater age. The large squares in the foreground show the groundwater age estimates derived from traditional methods (age tracer samples and lumped parameter modelling) from bores at depths between 16 - 25 m which have been used to train the model. The circles covering the background show predictions of groundwater age at a 20 m depth throughout the entire area at a 1x1 km grid. The colour scheme for both datasets is exactly the same, with red showing the youngest groundwater and green showing the oldest. The map on the right shows the training data and predictions at 50 m depth, indicating an increase in groundwater age at depth. Work to date shows that we are able to capture general trends of groundwater age with this statistical ('meta modelling') approach. We are currently exploring how we can better capture finer scale heterogeneity in age distributions (e.g. heterogeneity apparent in the shallower 20 m depth figure).



A quarterly newsletter for stakeholders of the TWOTW Research Programme

TWOTW PROGRAMME SUMMARY

Te Whakaheke o Te Wai (TWOTW) is a research programme funded by MBIE's Endeavour Fund and led by GNS Science. Originally planned to run for five years, the programme has been extended by another year. 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, Saphala 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