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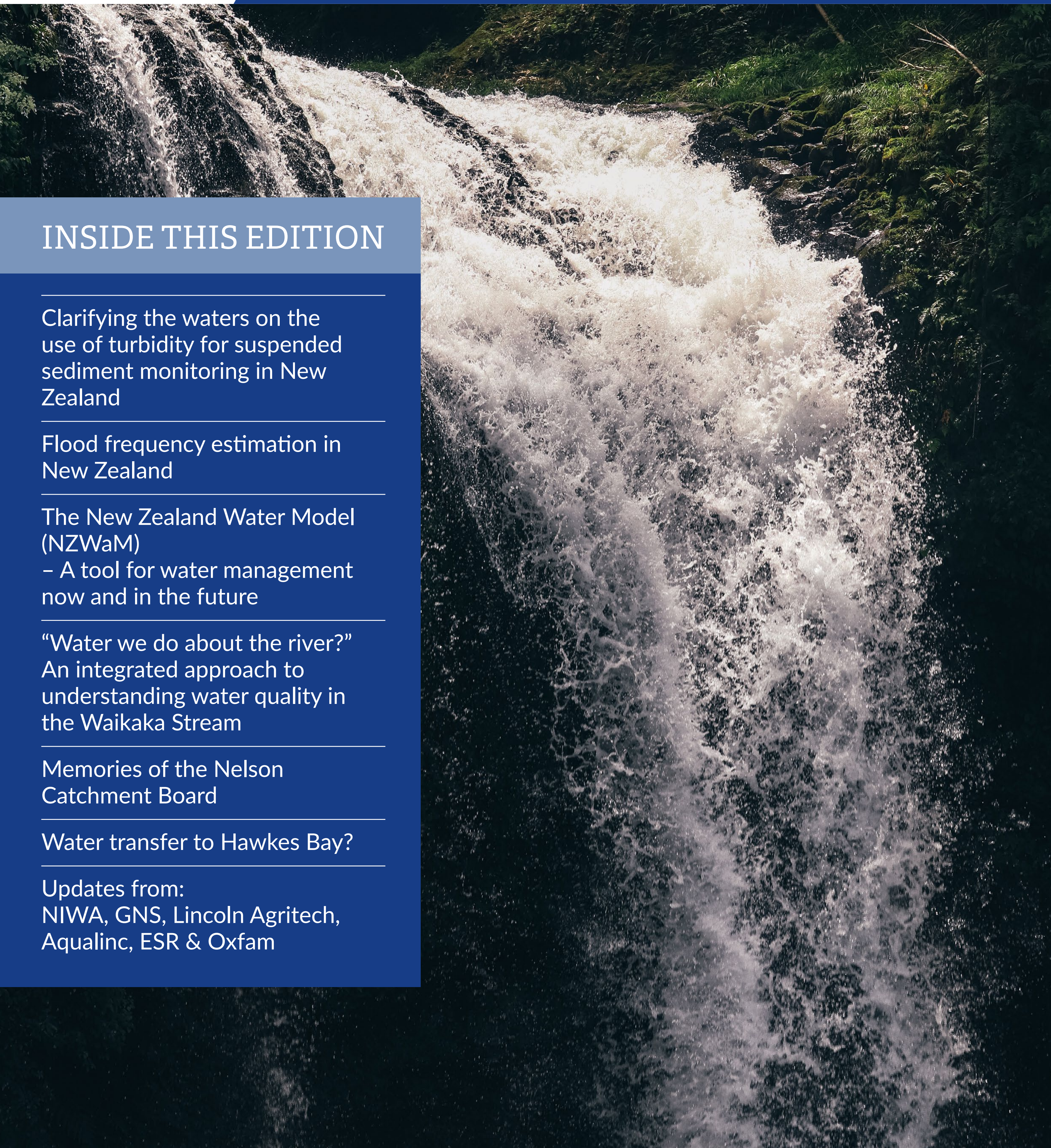
NEW ZEALAND HYDROLOGICAL SOCIETY

E-CURRENT NEWSLETTER



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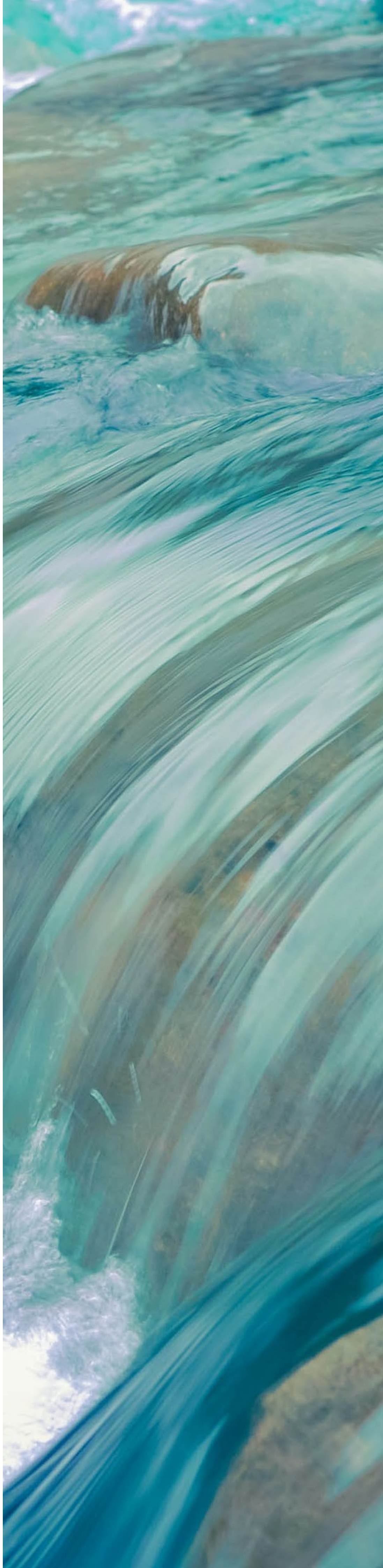
MESSAGE FROM THE EXECUTIVE

The New Zealand Hydrological Society annual conference will be held in the deep south in Invercargill/Waihōpai. Planning for the joint NZHS and Rivers group conference began in early 2020 not long after much of the lower South Island was transformed by intense rainfall producing flooding in Milford Sound/Piopiotahi where more than 1 m of rain fell in 60 hours in Milford Sound, as well as high flows surging down the Clutha Mata-Au threatening flooding to Balclutha/Iwikatea. These events inspired our theme for this years' annual conference Weathering the Storm, and seems to have been prescient towards the many challenges faced both at home and abroad in 2020. Planning for the annual conference proceeds apace and given the many conferences that have been delayed or cancelled we took the opportunity to invite the New Zealand Freshwaters Society to join our conference, so that this years event is a tripartite conference featuring experts in all fields of hydrology and water sciences. In early October we launched the draft programme of 230 oral presentations over 5 concurrent sessions and three days, and are thrilled with the support of the water sciences and hydrologists across the country. We were overwhelmed with over 290 abstracts for the conference and are really thrilled with the diverse range of themes, keynote presentations, and posters in this years programme.

On behalf of the conference organising committee we extend a warm Southland invite to the friendly south, as a gateway to the wild south: the rugged southern coastlines of the Catlins, the drowned valleys and primordial forests of Te-Rua-o-te-Moko/Fiordland National Park, or the birding and hiking wilderness of Rakiura/Stewart Island. We hope to be able to see you all in person in Invercargill/Waihōpai under these challenging times, but also have plans in place for any last minute changes in Covid-19 levels. For the first time at the annual conference we are working with IT providers to support virtual presentations and attendance, and plans for how to host a hybrid in person and virtual conference (if needed). We look forward to seeing you in Invercargill/Waihōpai to celebrate the incredible work in water sciences being undertaken across all sectors in New Zealand.

Sarah Mager
NZHS executive member



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ARTICLE

Christina Bright, Otago University

Clarifying the waters on the use of turbidity for suspended sediment monitoring in New Zealand

Research update from Doctoral candidate Christina Bright

In my last E-Current I provided an updated on my research that had been focused on understanding the behaviour of suspended sediment (SS) and particulate organic matter (POM) of southern New Zealand rivers. The outcomes from my doctoral thesis research covered four key themes with respect to the overarching focus on providing a critical analysis of turbidity and its role in environmental monitoring in New Zealand. The research themes were:

1. Particulate organic material can be a significant component of suspended particulate material (Bright & Mager, 2016; Bright *et al.*, 2018; 2020a)
2. Turbidity is sensitive to particle size distribution and mineral composition (Bright & Mager, 2020; Bright *et al.*, 2020b)
3. Specific turbidity as an index for sediment–turbidity monitoring suitability (Bright & Mager, 2020; Bright *et al.*, 2020b).
4. The future of turbidity and environmental monitoring in New Zealand

The research papers and thesis culminated with a synthesis and critical reflection on the use of turbidity in New Zealand as a regulatory tool and as a surrogate for suspended particulate concentration in rivers, which has been the focus of further thinking as the Essential Freshwater Package has been launched by central Government. Scientific research has ample examples of the shortcomings of the use of turbidity, yet it remains a commonly used surrogate for suspended sediment in river sciences for pragmatic reasons: including ease of use, and relative cost-effectiveness. However, it is the composition (i.e., particulate organic matter and coloured dissolved organic matter) and particle size factors (proportion of clay, silt and sand) that complicate the use of surrogates like turbidity due to the optical design of the instruments, particularly when the purpose of turbidity data collection is to derive records of suspended sediment.

Photo 1 shows a range of suspended sediments collected from a variety of southern New Zealand rivers, and highlights the diversity of suspended sediment types.

In New Zealand, there is advocacy for Water Plans to transition from using turbidity as an environmental threshold, and the recently gazetted National Policy Statement for Freshwater 2020 mandates the adoption of visual clarity as the indicator of degraded water from fine suspended sediment. Yet, existing water quality rules still require Regional Councils to use turbidity despite the known limitations. Discontinuing use of turbidity is unlikely an option given turbidity is imbedded in existing monitoring frameworks. However research has shown that there is potential for careful catchment-specific calibration of turbidity-suspended sediment relationships with metrics like the proportion of organic matter within total suspended load, i.e., the POM%, and specific turbidity, which is turbidity normalised for the mas concentration of sediment; these may be useful tools for diagnosing the appropriate conditions for turbidity use as a SS surrogate (see: Bright & Mager 2020b).

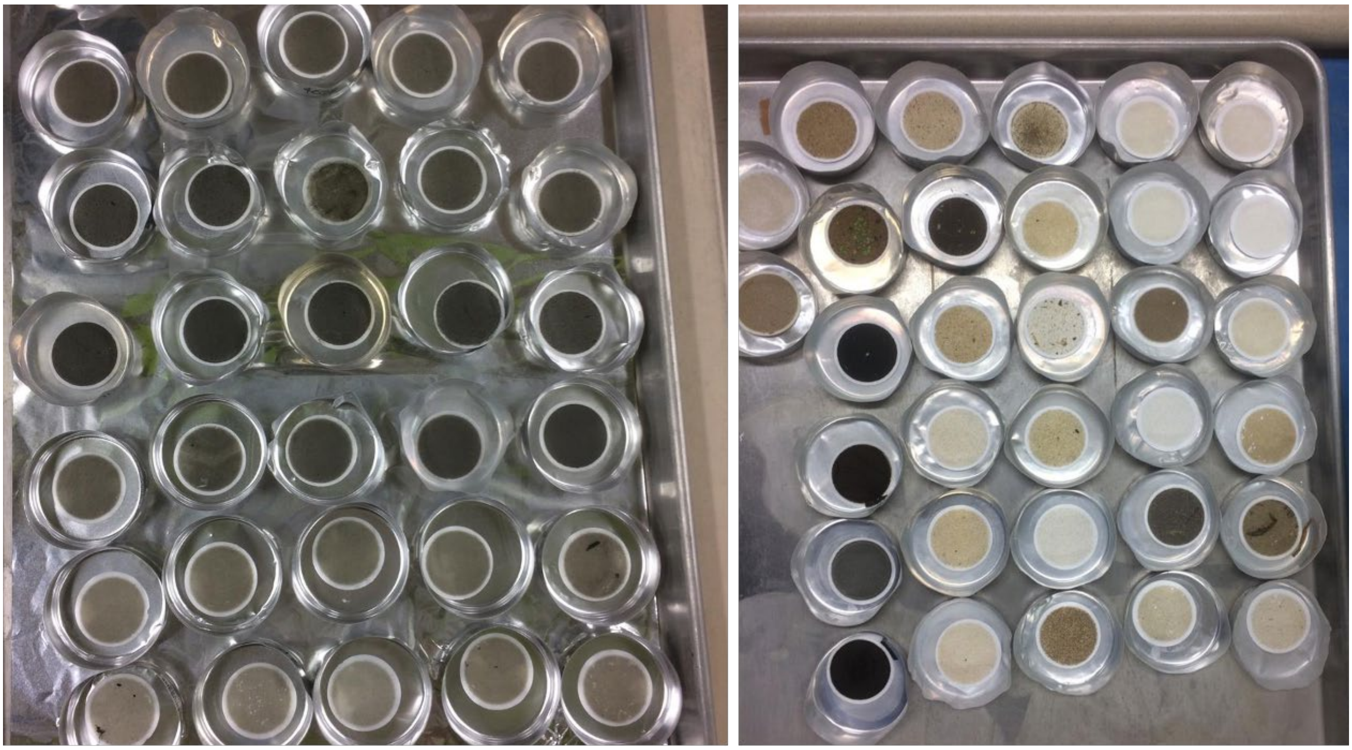

Photo 1: A range of suspended sediments collected from a variety of southern New Zealand rivers.

Phasing out use of turbidity to more reliable surrogates with continuous deployment options will take time, however, if turbidity is bespoke and rated carefully to catchment characteristics it can remain a suitable surrogate until these other technologies are available. Variables like POM% and specific turbidity may be useful intermediate steps to achieve this, and should be used more widely for classifying the effects of organic composition and particle size on riverine suspended materials.

For me, this research provides a thought provoking inevitability that in the short term continued use of turbidity will occur in New Zealand whilst other methods, such as automation of visual clarity, are not yet suitable for continuous deployment. All users of turbidity should consider the influence of its commonly reported shortcomings, and ask questions of their turbidity data:

- Can suspended sediment be derived from turbidity at a particular site, and can noise in existing suspended sediment-turbidity relationships be explained by higher portions of organic matter or fine particulate material?
- Are there certain landscape characteristics within a catchment that predispose the suspended flux to higher proportions of organic matter, or show a preference for the attrition of certain particle size fractions?
- Do existing suspended sediment-turbidity relationships vary in time and space, within and between catchments, and is this indicative of variable light attenuation responses to organic matter or particle size?

Turbidity is particularly flawed in certain landscapes where relationships between turbidity and suspended sediment are bespoke depending on its suspended material characteristics. In some instances, the relationship between turbidity and suspended sediment will be transient, and may reflect seasonal changes in material source (esp. if highly influenced by organic matter) and may be a source of considerable uncertainty in environmental monitoring.

Photo 2: A snow day at Glendhu Forest attending to the automatic metrological station, and fog collectors.

The second photo is of a snow day at Glendhu Forest attending to the automatic metrological station, and fog collectors. Glendhu is where my research interests in land use hydrology and suspended sediment, and the research outputs described here were initiated. Without the ongoing support for the Glendhu paid catchment studies by Landcare Research Manaaki Whenua and Barry Fahey and John Payne, the Otago Regional Council, the University of Otago, and Rayonier Matariki Forests, the paired catchment study that started in 1979 would not be running still today.

This research was supported by the New Zealand Hydrological Society Project Fund, and without such funding opportunities this research would not have been possible. I am extremely grateful to the Society for their enduring support of student research and participiation at workshops and conferences. If you are interested in hearing more about this work, I will be attending the 2020 annual NZHS conference in Invercargill, or contact me directly at: christina@landpro.co.nz.

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ARTICLE

George Griffiths, NIWA, Christchurch
Shailesh Singh, NIWA, Christchurch
Alistair McKerchar, NIWA, Christchurch

Flood frequency estimation in New Zealand

Introduction

Flood frequency analysis is concerned with how often a specified flood peak will occur at a given site on a river or stream. This information is important for example in the design of bridges, sewerage systems, and urban drainage. Analysis of floods and their potential impacts is also of the first importance to planners, consent and civil defense authorities and people likely to be affected by these events.

On a national scale flood frequency analysis in New Zealand has been carried out using the Index flood method. This involves firstly defining regions within which flood generation behavior in the various catchments of the region is similar. Secondly a method is developed to estimate mean annual flood at a given site on any river in the region and thirdly a regional growth curve is produced using annual maximum flood peak data from gauged sites in the region. The growth curve is usually a relationship between the ratio of annual maximum flood peak to mean annual flood versus return period- the inverse of the frequency of occurrence of a flood peak or the average time between exceedances of a given flood peak.

The first national flood frequency analysis in New Zealand was carried out by Beable and McKerchar (1982), They partitioned the country into eight regions and developed corresponding growth curves for return periods up to 200 years. Next, McKerchar and Pearson (1989,1990) produced contours of a mean annual flood parameter and a growth curve parameter for all New Zealand. In 1991 they undertook another regional flood frequency analysis for a small basins in New Zealand (McKerchar,1991; Pearson,1991). Henderson and Collins (2016,2018) updated the earlier work focusing on prediction of mean annual flood using multiple non-linear regression (MR) of catchment parameters namely area and mean annual rainfall and in the North Island hydrogeology as well.

Recently we tried another approach using the Index flood method but employing pooling groups of a similar catchments sourced from anywhere in New Zealand (Griffiths et al., 2020). This region of influence approach (ROI) often yields more accurate results (see for example, Ouarda et al., 2001; Haddad et al., 2015). Our focus was on predicting both the mean annual flood and the flood with a return period of 100 years as well as estimating in detail the errors involved and the reason for them excluding data measurement errors.

In this article we describe the method employed, the main results and some suggestions for future studies. Our intention is to inform the hydrological community about the history of flood frequency analysis New Zealand, it's present state and some needed future work.

Methods

The first step of the analysis was to select catchments with hydrological recording stations or gauged sites having similar flood generation characteristics to a nominated ungauged site on a river. A number of physiographic, climatic and hydrological variables including catchment area, mean annual rainfall, channel length, stream channel frequency, forest cover, soil drainage, depth-weighted micro porosity, minimum porosity, erosion index, hydrogeology index, mean elevation, main channel slope and mean annual 7-day low flow were chosen for use in the matching process. Originally, we wished to include rainfall intensity but determination of the appropriate rainfall duration for each catchment and the large variability in its accuracy of measurement among many catchments led us to adopt mean annual rainfall as a surrogate variable. A non-parametric regression technique was then used to determine which of the of the forgoing variables were diagnostic or significant in estimating mean annual flood. With this relationship found we employed a data depth function (Tukey, 1975), which measures how central a point is with respect to a cloud of data, to select a list of similar catchments with gauged sites to a nominated ungauged site. The last step was to take the geometric mean of the measured values of mean annual flood at the similar sites as the estimates of the mean annual flood at the ungauged site of interest. This averaging procedure was also used to predict the 100 year flood peak using the same similar sites as for mean annual flood.

To access the precision of the estimates of the mean annual and 100 year floods or the performance of our approach we used a resampling or leave one out procedure which consists of firstly considering each gauged site in a set of sites, say for the South Island, as an ungauged one and removing it temporarily from the set. The remaining sites are then used to find similar catchments and calculate a value of the

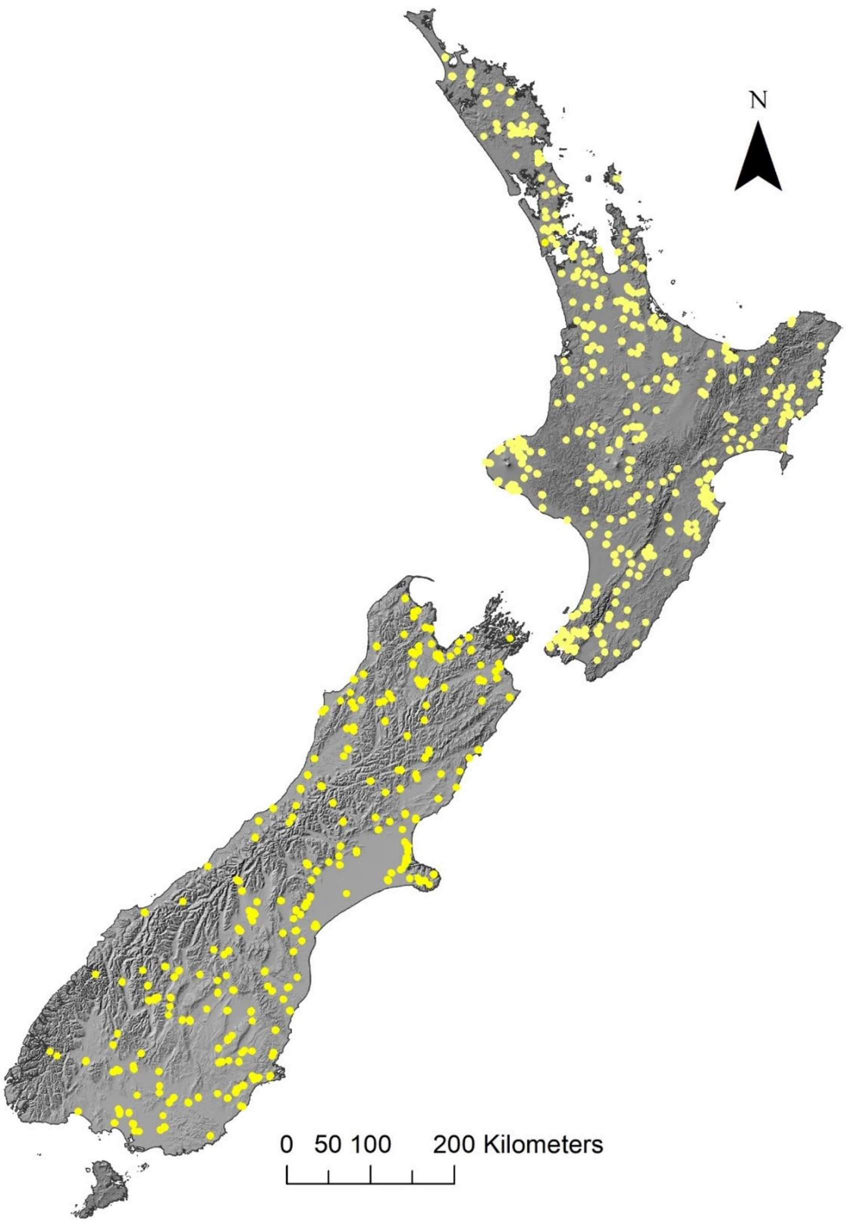

Figure 1: Location of New Zealand hydrological recording stations or sites used in the study.

mean annual and the 100 year flood. The process is repeated for all sites in the set and the average relative error or bias (ARE) and the relative root mean square error (RRMSE), or the standard deviation of relative errors are determined as percentage values.

For the North Island the number of sites was 362 and for the South Island 243 (Figure 1). Values of the mean annual flood were supplied by regional councils and NIWA staff from gauging site records and values of the 100 year flood were calculated from site annual maxima by fitting General Extreme Value distributions using L moments (Hosking and Wallis, 1997).

Results

We applied the region of influence method to estimate both mean annual flood and the 100 year flood in the North and South Island separately, treating each site in turn as an ungauged site and the remainder as a source of potential similar catchments. We also estimated these two flood peak magnitudes using the multiple nonlinear regression technique as was done in earlier work to predict mean annual flood. To determine the better method, we assessed the performance of each by calculating their ARE and RRMSE values.

For the North Island for mean annual flood it was found using the ROI method that the optimal result was almost invariably obtained by employing 12 similar catchments. Also, the only significant variables used to identify the similar catchments using data depth functions were catchment area and mean annual rainfall. With the MR method only area and rainfall were found to be significant as with the ROI approach. For the 100 year flood comparable findings were made with both methods. As regards performance, Table 1 lists ARE and RRMSE percentage values for the two methods. It is clear that there is not a lot of difference with the ARE values but the RRMSE values are substantially different indicating the ROI approach is superior to the MR approach.

For the South Island analogous results to the North Island were obtained except that for the 100 year flood the bias of the MR method was much larger than that of the ROI technique and the RRMSE values for both methods were fairly close.

The interesting question here is why the ARE and especially the RRMSE values even for the ROI method are so large. (Previous work does not help much as Beable and McKerchar (1982) and McKerchar and Pearson (1989) did not undertake an analysis of performance involving all sites. Henderson and Collins (2016, 2018) used the leave one out procedure as we did but excluded 5% of the data set as outliers and employed a record based weighting factor in the calculation of RRMSE,; consequently their results are not comparable to ours). Of course a better measure of the central tendency of a data set is the median. If this is used then, for example, the value of RRMSE for mean annual flood in the North Island of 164% in Table 1 reduces to 96%. To explore our errors result, we plotted number of sites as a proportion of the total number of sites versus RRMSE as shown for example in Figure 2 which applies to mean annual flood in the North Island. It can be seen there that the large average RRMSE values for all the sites of 164% (Table 1) mainly owe to the influence of a small number of sites which have flood generating characteristics leading to substantially different values of mean annual flood from those catchments treated as a similar catchments. Likewise for the 100 year flood in the North Island and for both floods in the South Island although there the effect of these outliers is somewhat less. The outliers are natural catchments which have, for instance, pumice soils, karst landscapes, glacial outwash deposits, rain shadows and hollows which provide extensive water storages during storms all of which may affect rainfall-runoff relationships to a significant degree. We were unable to discover any pattern, grouping or spatial trend regarding location or catchment characteristics for the outlier catchments. An influence here was that many of the outlier sites were originally installed to represent a group of catchments thought to be unlike any other group as part of a representative basin approach. Given the assumption of representativeness no other site installations were made. This causes substantive difficulties in applying a ROI or MR procedure for flood estimation.

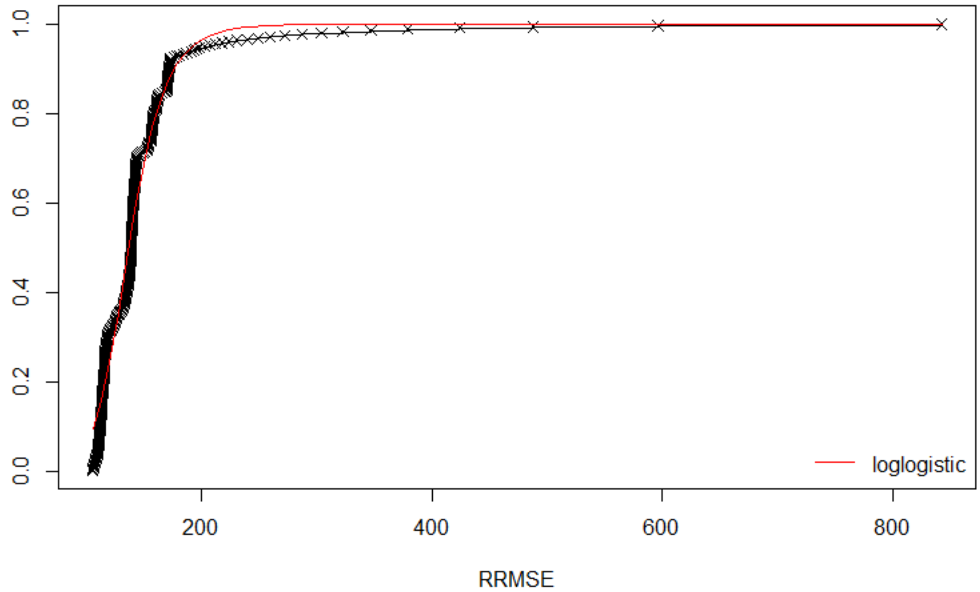

Figure 2: Relationship between proportion of sites and relative root mean square error.

Mean annual flood				
	North Island		South Island	
	ARE	RRMSE	ARE	RRMSE
ROI	47	164	30	123
MR	44	613	21	589

Hundred year flood				
	North Island		South Island	
	ARE	RRMSE	ARE	RRMSE
ROI	62	399	36	303
MR	70	485	60	355

Table 1: Performance of region of influence (ROI) and multiple nonlinear regression (MR) approaches for estimating mean annual flood and hundred year flood as assessed by average relative error (ARE) and relative root mean square error (RRMSE).

Future work

Apart from more data from catchments like those yielding large ARE and RRMSE values we have three other suggestions. Firstly, catchment mean annual rainfall should be replaced as a catchment characteristic by rainfall intensity of an appropriate duration; finding this duration is normally a difficult problem. Secondly, in the meantime, more precise estimation of mean annual rainfall could be made using measured annual values of runoff less evapotranspiration as significant differences were often observed between the values calculated by this method as opposed to those estimated from raingauge data. Thirdly, rainfall-runoff models often can predict the size of a flood peak quite accurately given input rainfall and catchment characteristics but not the return period of the peak as this is normally different from that of the specified return period of the rainfall. And it is the return period of the peak that is the main objective of flood frequency analysis.

Conclusions

Considerable progress has been made in flood frequency analysis in New Zealand over the past 40 odd years. But there is certainly a need for further investigation. In our study we found that prediction of the mean annual flood and the hundred year flood at a given ungauged site is on average achieved with less relative bias and relative root mean square error using a region of influence rather than a conventional multiple regression approach. Also a probable reason for the substantial error magnitudes is the disproportionate contribution from a small number of outliers in the flood peak data. The outliers are natural catchments which have particular characteristics which affect flood generation in a way as to render them almost unique. Finally we believe that a material improvement in results could be gained by employing catchment rainfall intensity of appropriate duration instead of catchment mean annual rainfall as a characteristic variable, or at least using the latter estimated from catchment flow data wherever possible.

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ARTICLE

James Griffiths, NIWA
Christian Zammit, NIWA

The New Zealand Water Model (NZWaM) – A tool for water management now and in the future

Introduction

Freshwater management generally has two aims: to achieve sustainable use of water as a resource and to minimise uncertainty associated with management action (e.g. consenting water takes and limits-setting). Sustainable use of water means that water (of required quality) will continue to be available in sufficient quantities and to meet the needs of society and ecosystems. Minimising uncertainty means reducing the likelihood that management action will have unintended consequences. The most obvious unintended consequence would be river drying and fish kills due to excessive water allocation. To achieve the above aims, hydrological models are needed to predict the impacts of water and land use, environmental variability, and management action on water availability and quality and ecosystem response.

Models are needed because it is impossible to directly observe environmental variables at all locations, all the time or in the future. Models can therefore help us to make reliable predictions in ungauged catchments and about future conditions. Models that can be used to improve water management in New Zealand need to be flexible enough to represent a wide range of environmental conditions, but complex enough to represent the integration of both natural and anthropogenic processes (such as those shown in Figure 1). To address the above need, NIWA is leading the development of the **New Zealand Water Model (NZWaM).**

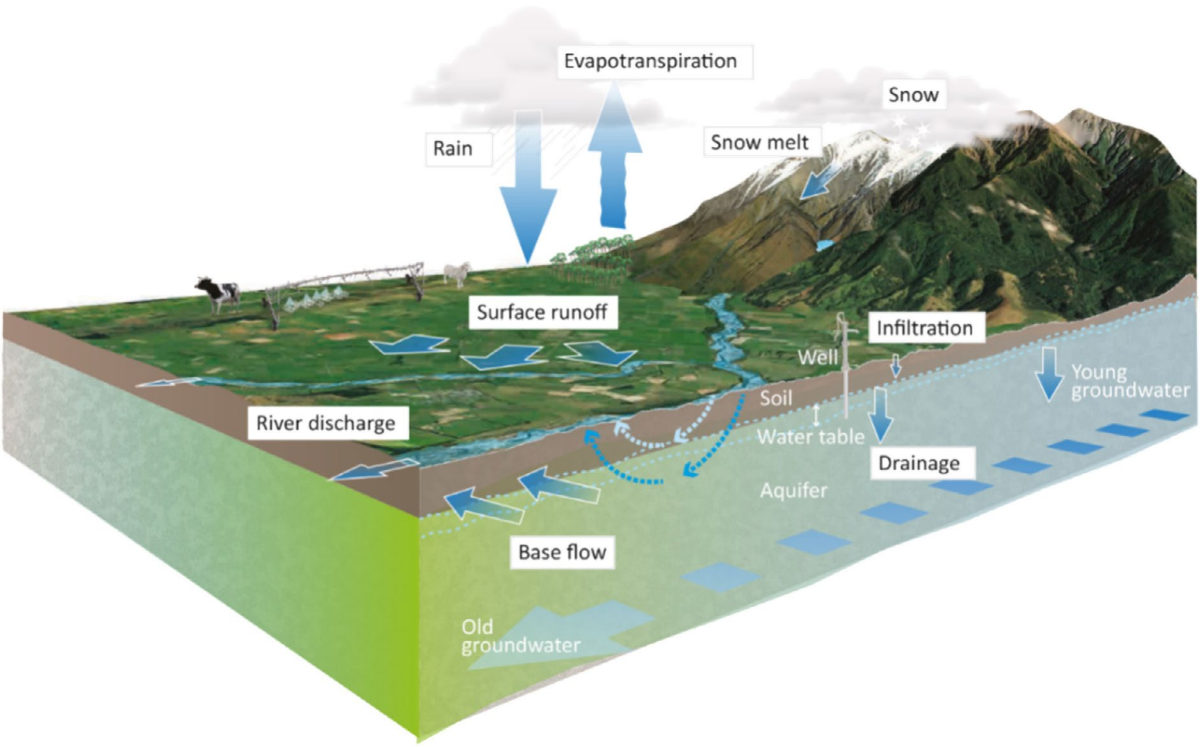


Figure 1: Hydrological processes that are represented in the New Zealand Water Model.

NZWaM adopts a modular design approach that links a wide range of environmental data with sub-models representing different hydrological, ecological and water quality processes. These sub-models can be added as they are developed. The physical domain of processes represented within NZWaM extends from the top of the atmosphere, to rivers, lakes, aquifers and estuaries.

NZWaM-Hydro

NZWaM-Hydro is the first component of the NZWaM platform to be completed. It provides essential hydrological information for water management and planning at a national, regional, catchment, and sub-catchment scale. NZWaM-Hydro is being used for national and regional policy development, water allocation and flow setting, water accounting, and flow forecasting (both flood and drought). NZWaM-Hydro will be coupled to sub-models for water quality (NZWaM-Water Quality) and ecology (NZWaM-Ecology) as they are developed.

Background

From 2016 to 2018, the development of NZWaM-Hydro focused on the construction of the hydro-geofabric for the capture and storage of multi-scaled hydrological information. The surface water flow model and an associated national-scale river-flow forecasting tool became operational and associated flow-forecasting tools were tested with stakeholders. In 2019, data from the hydro-geofabric was used to conceptualise groundwater systems, and thus improve predictions of groundwater variation in space and time.

The user-interface, 'NZWaM-HydroDesk', allows users to access data and model simulations held within the hydro-geofabric. NZWaM-HydroDesk was released in June 2020. Data quality checking and benchmarking, and improvements to the user-interface and hydro-geofabric are currently being implemented. All components of NZWaM-Hydro will be completed by 2022.

NZWaM-Hydro was developed by a partnership of NIWA, GNS Science, Manaaki Whenua - Landcare Research, Ministry for the Environment, Ministry for Primary Industries, and regional and district councils (Southland, Horizons and Gisborne).

Key components of NZWaM-Hydro

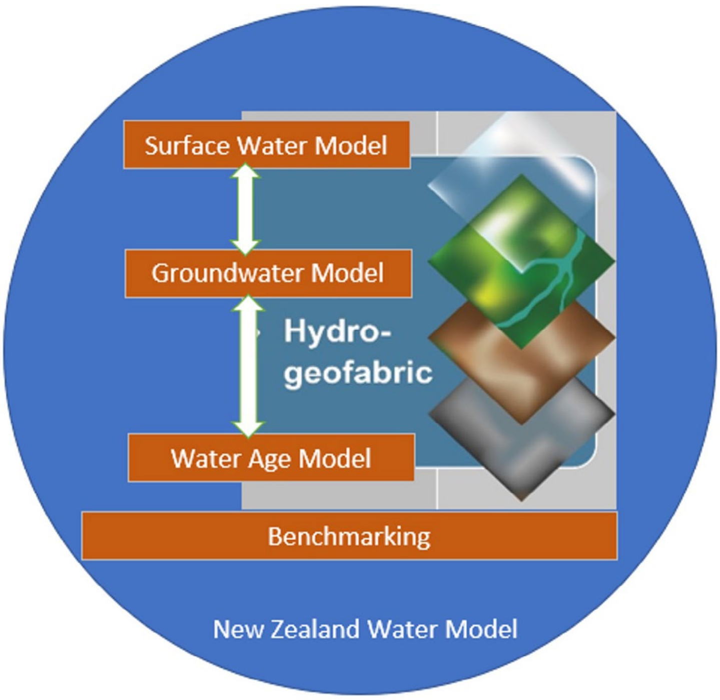


Figure 2: Key components of the NZWaM-Hydro modelling framework.

Figure 2 illustrates the key components of NZWaM-Hydro. At the core of NZWaM-Hydro **lies the hydro-geofabric,** a dynamic geospatial database. The hydro-geofabric stores measured data (updated digital river network, soil data, geological information, water isotope data, land use data, and climate data), and derived parameter data (soil saturation, hydraulic conductivity, etc). New environmental data for the hydro-geofabric is continuously being collected by NIWA in collaboration with regional and district councils.

NZWaM-Hydro's **surface water model** is based on NIWA's TopNet rainfall-runoff model and is used for environmental flow setting and for evaluating water resource availability. This model will represent evaporation, soil-moisture and groundwater recharge processes using soil, landcover and climate data held in the hydro-geofabric. The model has been tested in a range of environments and catchment types to assess its applicability and performance in all regions of the country.

The **groundwater model** used in NZWaM-Hydro is based on the GNS National Water Table (NWT) model. It is used to determine aquifer hydraulic properties and predict groundwater fluxes. Models are built using data from the hydro-geofabric, a knowledge of the location of measured surface-groundwater interaction, and water-table position indicated by the EWT model.

A **water-age model** is being developed with surface and groundwater isotope data from ongoing survey work by regional councils. The isotope data is being used to identify the origin of stream water (i.e. direct rainfall, shallow sub-surface water or deep groundwater). This information will then be used to identify flow pathways between river networks and aquifers.

The surface water and groundwater models are coupled to represent water exchange between land, surface-water bodies and aquifers, and the water age model specifies the location and rate of water exchange. The three models are currently run on a cloud-based system which eases user interaction and roll-out of software updates.

Model **benchmarking** uses state-of-the-art methods to test each of the above models against observed data. Guidance on the use and limitations associated with the models is currently being produced.

New Developments

The latest update of the augmented precipitation research dataset (to 2019), developed using Virtual Climate Network (VCSN) processes, will be completed in November (2020). This dataset will consist of the operational daily precipitation and daily precipitation bias.

A beta version of Hydrodesk-NZ will be released at the HydroSoc conference in December. The online tool will allow registered users to run a national scale surface water model (TopNet rainfall-runoff model) for any catchment in New Zealand.

The Hydro-geofabric, the geo-spatial database that forms the spatial architecture of NZWaM, will become accessible to registered users at the end of this year. The database consists of a wealth of harmonised hydro-geo-spatial information invaluable to modelling hydrology in New Zealand.

For more information about NZWaM-Hydro, contact Dr Christian Zammit (christian.zammit@niwa.co.nz).

ARTICLE

Jessica McIntyre, University of Otago

"Water we do about the river?" An integrated approach to understanding water quality in the Waikaka Stream, Southland, New Zealand

My research focused on understanding the development and potential role of community management that is emerging through the formation of catchment groups. I completed field work over a 12 month period, to understand and quantify the current water quality of the Waikaka Stream in Southland, and the local community perceptions and values of the stream. Monthly water samples provided an evaluation of the stream water quality under base flow conditions, which indicated challenges meeting current guidelines for nutrients, sediment, and E.coli – the latter being particularly high in the upper catchment, and nutrient (nitrogen and phosphorus) concentrations in the lower catchment. These results implicate wild populations of ducks, and deer as a major cause of high E.coli concentrations in the upper catchment, whereas cumulative impacts from pastoral farming likely explain the patterns of nutrients in the lower part of the catchment.

Key informant interviews provided insight into the views of local farmers towards the water quality of their local stream. The results showed that farmers perceptions did not align with the physical water quality, thus highlighting both the threat of hidden water quality issues, and the difficulties in aligning local perceptions of water to regulatory thresholds. The divergence of understanding between meaured and perceived water quality has led to distrust and upset between the community and regulators, making the collaborative process difficult, and causing frustration amongst the community which ultimately stimulated the creation of the local catchment group. The catchment group has the potential to fill the perceived management gap in the stream community, while supporting farmers, building social capital, and collaborating knowledge – but are not as yet established as a legitimate, and equal, partners in local freshwater management. There remains much work towards engaging community groups into effective 'bottom-up' management of freshwater and an opportunity to help establish local-led community groups to develop greater structure and govenance for meaningful partnerships with local government and tangata whenua. My research provided valuable insights into the local dynamics of how and why water quality is contested and the challenges of blending the perspectives and measures of water quality in rural New Zealand. Thanks to the New Zealand Hydrological Society for the Project Grant, which made my research possible, and to the locals who volunteered their time and insights to my research. I look forward to the next step of liaising with the local community about the outcomes of the research and possible next stages.

ARTICLE

Jim Black, Nelson Catchment Board

Memories of the Nelson Catchment Board – Notes sent to Martin Doyle, Tasman District Council

The following memories were provided by Jim Black, who worked for the Nelson Catchment Board for a summer after leaving High School and prior to heading off to University. Several photos from the archives at Tasman District Council have been added to Jim's story, along with some comments in brackets.

My last school holiday job, over the 1966 - 1967 Christmas break until it was time to go to university, was with the Nelson Catchment Board. I had a contact in the chairman, a Mr Petersen, a dignified gentleman whom I had met through the Forest and Bird Protection Society.

Since these local bodies no longer exist, I will explain what I knew of their work. The catchment here meant all water falling on and passing through or under the Waimea Plains and all the area east of the Takaka Hill. I cannot remember if the other side of the Takaka Hill was included in our results. It was defined by the ranges, so anything flowing northward into Tasman Bay fell into their scope. They set up a network of rain gauges and water level recorders. The latter were in tubes beside streams and had recording equipment, clockwork driven, whose results appeared on graphs drawn by the machines.

Figure 1: Red Hill raingauge – installed about 1965.

The rain gauges that were quite remote were also automatic, in the sense that they also had recording equipment and at their most elaborate would empty and reset themselves when they were full. Someone still had to collect the graphs from them. Many others were read manually. There would be the gauge itself, an open tube of known diameter, and a dipstick calibrated to match that usually sat in the tube and was withdrawn to be read. If they were beside tracks, such as one at Coads Creek on the Dun Track, the public were encouraged to read them and to record the date and water level in a book in a sealed box on a post. Every so often a staff member did the rounds and emptied them [some of these raingauges still exist and passing trampers stumble upon them in the scrub and send returns in (sadly useless), including one from the Red Hills raingauge (figure 1) which was mailed from Kununurra in Northern Australia…].

The idea was that rainfall patterns in a particular river catchment could be recorded and compared with the rise and fall of the river flowing out. Then the whole catchment could likewise have its areas compared. Eventually there would be enough data to start predicting what sort of rain in a given watershed would produce a flood and how quickly. They were also measuring water levels in bores and wells. Even then there was concern about the aquifer under the Waimea Plains.

As this was pre computer, all the graphs and readings had to be manually collected, returned to the office and transferred to permanent form as tables and logarithmic graphs. When I got the job of doing this, the pile of graphs and notebooks unanalysed went back five years. That is, all the information collected between about 1962 and 1967 from some thirty sites and different instruments had to be collated.

I was considered qualified because I had passed School Certificate mathematics. I was set down at an enormous desk in a vast open office, where one other rather elderly man also worked, at what I never found out, probably because he was rather forbidding and I never asked. I had a very beautiful desk set of two self-filling dip pens that sat in inkwells of black and red ink, and an adding machine whose digits column was unreliable. I would add a foolscap column of figures with this thing, entering each number by pulling a handle. When the total finally was reached, I would manually add all the last figures to make sure the machine had not lied. If it had, the calculation would be repeated until the figures were reconciled. So pencil work came first. Finally, the figure would be carefully inked onto a ledger. And even more finally, a total set of results went onto a book of logarithmic graphs. These I did in pencil before I dared to ink them in.

Figure 2: Flow gauging by jetboat, Dave Tamm driving, Lower Waimea River, 1960s.

Every week or so, the field staff would take pity on me and we would drive out in the firm's yellow Landrover to collect results or maintain the equipment. I learned what the mysterious towers on riverbanks with their blank iron doors were actually for. On my return to the records, I developed an idea of what actually must be going on at these places when the circular and drum graphs started to suddenly show a spike. When I did the comparison with the rainfall data upstream over the same time, it became fascinating. Now and then the staff also measured water speed with a thing that looked like a torpedo that they ran out along a cable across the water. With this, and with the known profile of the river at cross sections beside the level recorders, speed and volume, not to mention acceleration and volume at depths, gave an illuminating and often awe inspiring idea of what was going on.

Part of the fun was access to their records. Although the catchment had been surveyed for the NZMS 1 map series, these maps had some very sketchy sections. Dotted lines for rivers were common, with descriptions like "Rough mountainous country. Heavy bush." Of course all surveying was done as it had been in the days of Charlie Douglas, with theodolite and compass. The maps themselves were beautifully hand drawn and coloured. There are archives of these maps kept and they are worth looking at for their craftsmanship.

To get a better view, the whole area was photographed from the air in black and white. The sharpness of the images were startling. You would put a foolscap sized page on the bench and then use a stereoscopic viewer, two lenses set on short folding legs. The detail that appeared was sharper than a Google image, possibly because chemical photography gives detail at the molecular rather than a pixel level. One still had to correct mentally at times for reverse image, where one's mind saw ridges as valleys. Other detail relevant to hydrologists was vegetation cover, which of course affects runoff. This was not part of my job, but gave a useful background to my records and calculations, and kept my interest up when the wretched adding machine had sapped it. There were also photos of the rain gauge sites themselves, useful if a party had to go out and actually visit these elusive creatures, which by virtue of being set in the ground without structures about them to interfere with raindrops could be quite tricky to find.

The automatic rain gauge on the Dun Mountain was in a cyclone netting fence, as it was pretty valuable and was accessible to the tramping public. There was a corrugated iron hut with a stove and two bunks for the instrument readers in case of bad weather. Nearby, facing along the length of Rocks Ridge, was the doorless toilet. This costly instrument - that is, the rain gauge - had been delivered in a packing case by air, pushed out of a De Havilland Dominie biplane passing by at about twenty feet above the ground. The photos prove that this was how things were done before helicopters [Unfortunately - this photo of the install cannot be found, but the following photos shows a subsequent visit to this site by helicopter].

Figure 3: Helicopter visit to Dun Mountain Raingauge.

The local population could be interesting. I went along with the crew to put in a rain gauge that had been delivered in parts to Beebys Knob, a feature on the way to Lake Rotoiti. The weather was not promising. We parked at where we were to start walking, and waited for the cloud and rain to lift. This was wise, as the destination was an open, grassy hillside with few useful features to help us find our way. In the absence of the future help of GPS, we gave up for the morning and it was decided to wait in the shelter of the Tophouse Hotel. We were the sole visitors that day and had the bar to wait in. For those who have not known this establishment, a few words might be interesting. It was a cob single storey building, whitewashed on the outside with wide eaves. There was a dining room with a colossal fireplace with inglenooks. I was told that this place was much favoured by the skiing set from Mt Robert, many of whom had cribs at St Arnaud and money to spend. Everybody knew about the terrible tragedy of an early licensee having shot himself on a bench outside. The bullet or pellet marks were still on the wall for all to admire. The bar was attached to the main building and was a later addition. It was about eight feet square, with a bar counter splitting it exactly. Behind the bar was a huge keg of beer, a set of shelves with a very limited range of spirits, and the owner and licensee himself. One leant on the counter with one foot on the foot rail and listened.

The man was nicknamed Flannelfoot, because he always wore carpet slippers. He had an endless supply of anecdotes about the local history. The one I remember was about a bushfire in the 1930s at a forest still known as Big Bush, native beech forest. All available men were called on to fight it. As volunteers they were paid. Times were tough, so they kept the fire going for some time longer than was decent. The hotel toilet was off limits to drinkers, who had to use a shed outside formed entirely of corrugated iron. This caused the eventual end of the hotel's licence. When it came up for renewal, authority declared that this shed had to go. Locals, including the skiers, turned out to build a proper, or at least acceptable toilet. Apparently the owner's wife upset the volunteers by insisting that they bring their own lunch. They downed tools and never returned. So ended the oldest continuous hotel licence in New Zealand.

My fellow workers began drinking beer. I was offered some, but refused and discovered sarsaparilla for the first and almost last time. They did not insist, but suggested that if I was really off to university in a few months, I had better get in some practice sometime. The rain persisted and the men kept drinking. At about three o'clock they decided to go home, as it was a point of honour to always finish work at five. I did offer to drive the Landrover, after a few rather alarming swerves, but they said not to worry, they'd be fine. We went back to Beebys Knob on a day when the weather was better and dug in the rain gauge [The gauge still exists, but is not used. A photo below shows a nearby gauge installed about the same time].

Figure 4: 'Shorty' Taylor after installing raingauge on Gordons Knob Jan 1965, about the same time as Jim worked for NCB.

I revisited the Tophouse Hotel a year or so later, not long before it closed, had a beer and listened to the same set of tales in the same order as on my first visit.

The last act in the office was a real test of my mathematics. Many of the gauges were manual and had to be visited to get the pages filled in by the public. All the others were clockwork and had to be rewound regularly and the paper records taken, with the little pens re-inked and new graphs inserted. Then someone like myself had to collate all the results. The plan was to remove all gauges apart from a representative few in each watershed. By calculating the pattern of rainfall established from the data gathered to date, a reading from a readily accessible gauge should be able to give an idea of the rise in any given river. I was requested to come up with a suitable useable formula to make this sort of prediction possible. My overseer seemed to think that what I came up with was satisfactory. I can only hope that this and all my three months of calculations did not lead to any horrendous misadventures.

They offered to have me back, now that I was nicely trained in their ways. But by then the NZED had put in a counter offer at a pay rate that a local body could not match. I thoroughly enjoyed my stay and the people I worked with. It is a pity, perhaps, that young people seem now to have so few chances to engage in this sort of work.

ARTICLE

Earl Bardsley, University of Waikato
Yasaman Karaminik, University of Waikato

Water transfer to Hawkes Bay?

Introduction

New Zealand has seen limited development of inter-catchment water transfers. The Rangitata Diversion race is probably the best known, with some Rangitata River water being diverted to the Rakaia River along a 67 km canal to provide irrigation and some hydro power. The Tongariro Power Scheme uses a series of tunnels to transfer additional water for power generation, obtained from the headwaters of the Whanganui, Rangitikei, and Whangaehu Rivers.

However, there has been no inter-climatic regional water transfers given serious consideration, in the sense of moving water from a wetter to a drier part of New Zealand. The closest to the concept has been the occasional suggestion of a tunnel through the Southern Alps to transfer Westland river water to Canterbury or Otago.

Motivation for more serious consideration of west-east water transfer comes from the possibility of climate change bringing more frequent droughts to eastern regions. A recent NIWA report indicates that for Gisborne and Hawkes Bay there will be a substantially increased risk of drought, and river discharge could decrease by up to 20 per cent by 2090. A brief overview is given here for potential water transfer from the Central North Island to Hawkes Bay, which has recently suffered one of its worst droughts on record.

Figure 1: Water transfer by the Tongariro Power Scheme into the Waikato River catchment on 27/10/2020: Moaphango tunnel discharge to the upper Tongariro River (left) and Wairehu Canal discharge (right).

Taupo water to Hawkes Bay?

Inter-catchment water transfers inevitably have environmental impact on the source rivers, which are reduced in discharge. In fact, the present diversions of the Tongariro Power Scheme can be regarded as the first stage of a future water transfer to Hawkes Bay. That is, the source diversions are already in place. The discharges involved are considerable and average in the order of 15 m3s-1 under the present operation of the Tongariro Power Scheme (Fig. 1).

Of course, it would be ridiculous to think of constructing a pipeline to transfer water from Lake Taupo to Hawkes Bay. However, the concept may be more feasible in the context of combined water transfer and pumped storage to buffer dry years, in support of the stated national goal of 100% renewable power generation.

In this regard, the Ministry of Business, Innovation and Employment (MBIE) has been tasked with an overview of dry year mitigation options, with particular reference to pumped storage. As can be seen at their NZ Battery web page, emphasis will be on the large energy storage capacity of Lake Onslow in Central Otago. However, some North Island pumped storage sites are to be considered as well. Although these sites have not yet been identified by MBIE, the largest energy storage capacity would appear to be in the basin of the upper Ngaruroro River, to the east of Lake Taupo.

Ngaruroro pumped storage

Constructed to its largest energy storage capacity, the Ngaruroro Scheme would require a high 120 metre dam in the upper Ngaruroro River. There would also need to be low embankment dams at three saddles on the lake's eastern margin. The main dam would be located just downstream of the Panoko Stream confluence and would create a reservoir lake of surface area 32 km2 lake at 1040 metres maximum elevation (Fig. 2). Permitting the lake to be drawn down from 1040 to 1000 metres in dry years would give a gravitation potential energy that would increase national hydro storage capacity by more than 50%.

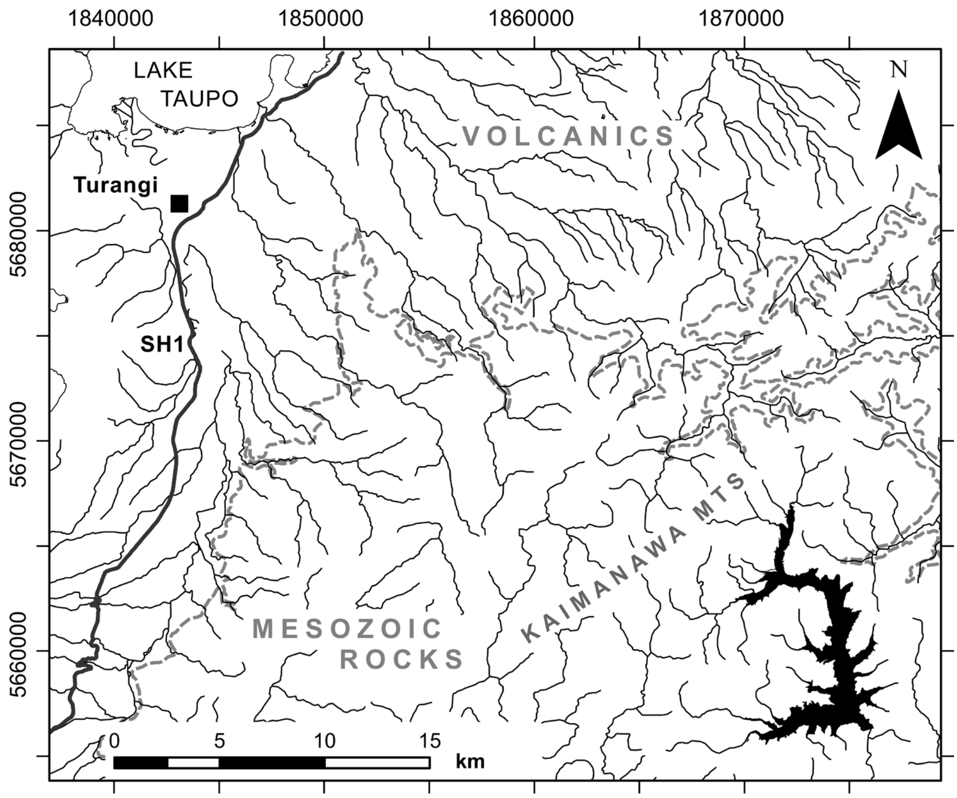


Figure 2: Location of the pumped storage upper reservoir lake (black) in the Ngaruroro River headwaters. Dashed line indicates the boundary between Mesozoic sediments and volcanic rock units around Lake Taupo. Linkage tunnel to Lake Taupo is not shown.

The new lake would serve as the upper reservoir of a pumped storage scheme with transfer of water back and forth to Lake Taupo, along a 30 km tunnel. The to-and-fro discharge might be, 75 m3s-1, coupled with 500 MW installed pump/generating capacity.

Lake Onslow has a greater energy storage capacity and shorter tunnel length. Also, Onslow pumped storage could more readily be constructed for ancillary pumped storage services outside of dry years. On the other hand, Ngaruroro pumped storage would serve a dual purpose of water transfer to Hawkes Bay. That is, there could be up to 15 m3s-1 discharge along a gravity flow pipeline to Hawkes Bay from the new lake, generating power along the way to offset the cost of the water purchase.

Implications

There are a great many implications involved in such a massive civil engineering project, should it ever happen.

In particular, there is the environmental impact of creating a large new lake by flooding a scenic valley (Fig. 3), with some of the lake extending into parts of the Kaweka and Kaimanawa forest parks. If the lake was created, it would need to be as dry year "last resort" hydro storage with only small water level variation in normal years. That is, the lake would have to appear like a small version of Lake Waikaremoana almost all of the time. Even with those constraints, it could be decided that the environmental impact could not justify the water supply and power security advantages of the scheme. It is also noted that the current regulations of the Hawkes Bay Regional Council do not permit water storage in the upper Ngaruroro River.

Figure 3: View over the upper Ngaruroro River from Waitawhero Saddle. The 1000-metre contour is approximately the line of the lower bush level. Further imagery can be obtained from the source.

However, there are also some environmental gains from such a water transfer. The transfer volumes involved could be sufficient to greatly reduce the present extractions from the Hawkes Bay rivers and groundwater, thus increasing river low flow discharges and water quality to more natural levels. There should also be improvements in urban drinking water quality and reliability, assuming the new water could be reticulated around the region. There are a great many local options that would need to be considered as well, such as whether some of the new water might go to groundwater recharge schemes or to intermediate lower-level reservoirs for drought reserve.

There is also the interesting issue of who has the right to the water from the Tongariro Power Scheme diversions. The question has never arisen because the only option has been as a discharge increment down the Waikato River. However, the argument could equally be made that this diverted water is better utilised to improve the agricultural economy of the Hawkes Bay region rather than artificially increasing the mean discharge of the Waikato River.

Finally, it would not seem possible that the Ngaruroro water transfer scheme could ever proceed to construction unless it was driven and motivated by the iwi involved, as full economic partners with a permanent income stream to follow. For example, the Tuwharetoa iwi from the source water should have a say as to the ultimate fate of the Tongariro diversions in a water balance sense.

Conclusion

The water transfer scheme to Hawkes Bay may or may not ever come to fruition. However, in these present unusual times there could be scope for large projects like Onslow and Ngaruroro to play a role in the economic recovery process. As a dual system, Ngaruroro is many-faceted and would require more detailed consideration than Onslow. To this end, it would be helpful to have a preliminary overview study on record. In this regard, an author of this note (YK) is starting a PhD study at the University of Waikato and is seeking scholarship funding. Regional councils cannot be reasonably expected to fund investigations in contradiction to their environmental regulations, but perhaps there are potential water users in Hawkes Bay who might help in this respect?

Acknowledgement

Upper reservoir volume integrals and location map were created by Oliver McLeod, University of Waikato.

UPDATE

James Grifiths

NIWA Update

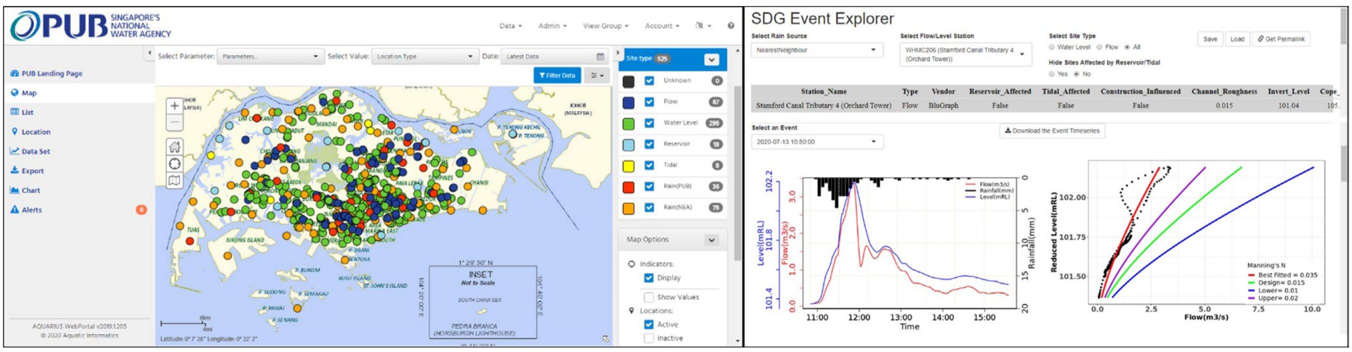
2020 continues to be a challenging year, and during the various alert levels that have been in place since May, NIWA staff have striven to return to a new kind normal through a combination of home-working, virtual meetings and an increase in field activities. Where field programs (particularly in the Pacific) continue to be impacted by international travel restrictions, NIWA have been conducting remote support activities with collaborative in-country organisations and clients. This and other highlights from the last six months at NIWA below.

NZ Flood Inundation Assessment

MBIE have awarded a NIWA-led research team $15.3 million to create the first comprehensive flood inundation assessment for Aotearoa New Zealand. The programme will look at increasing rainfall and rising seas under current and future climate projections. The work is being led by Emily Lane, Christchurch-based hydrodynamics scientist and Resilience to Hazards programme leader, and Sam Dean, principal climate scientist in Wellington. Other research providers and stakeholders involved include universities, CRIs, iwi, National Science Challenges, councils, central government and industry. The research will ill reveal how our flood risk might change over the next 100 years because of changes to rainfall and sea level from climate change, as well as land-use changes.

Smart Drainage

NIWA recently developed the ‘Smart Drainage Grid’ system, for storage and analysis of historical and real-time environmental data for the Public Utility Board in Singapore. The Aquarius Time Series system was used to integrate reporting of reservoir, drainage, sea level, and rainfall timeseries. The system provides automatic data checking and reporting for observed data and allows derivation of synthetic catchment rainfall time series from radar data and observation data. This allows the drainage water level and flow responses to be connected to the rainfall input. The system will be used to derive Intensity Duration Frequency (IDF) statistics for different regions in Singapore and will provide notification of unusual events based on user defined criteria. [Jochen Schmidt, Mike Bargh, Shailesh Singh, Murray Kinsman, Tony Hill, Raghav Srinivasan].



Map and user-interface of the ‘Smart Drainage Grid’ system

Strategy for Irrigation

NIWA are developing an irrigation tool to evaluate the economic and environmental returns from improved irrigation practices. The tool will help farmers evaluate the performance of different irrigation practices relative to water use efficiency metrics: amount of irrigation used, drainage resulting from poor irrigation practices, and how well the soil water conditions are maintained for maximum crop growth. It does this by considering on and off-farm information including rainfall, evaporation, soil type, type of irrigation system, availability of supply on-demand and economic cost of poor irrigation practices and evaluates them for three irrigation practices. The tool will help farmers to build an economic and environmental business case to overcome those controls and strategically invest on irrigation infrastructure and practices that maximise the economic return and minimise the environmental footprint. [Irrigationinsight.co.nz].

Hydrology in Forested Catchments

NIWA hydrologists and field teams are contributing to a 5-year MBIE Endeavour research programme led by Scion. The 'Forest Flows' programme will help increase our understanding of spatio-temporal variation in water-uptake by trees in planted forests. NIWA is contracted to provide meteorological, biogeochemical, groundwater and streamflow measurements, and modelling expertise. This research will help understand the influence of upland forests on lowland water resources. The wider research team includes experts on tree physiology, remote-sensing, data modelling, Māori relationships and socio-economic impacts. [Bruce Dudley, Alec Dempster, Rod McKay]

Initiating field survey work in Mahurangi Forest (photo: Alec Dempster)

Streamflow Depletion

In New Zealand, river flow regimes in many catchments are influenced by multiple groundwater abstractions. NIWA has developed a model for predicting cumulative streamflow depletion across entire catchments at daily time-steps. The model uses two different analytical solutions to estimate streamflow depletion due to groundwater pumping from shallow and deep aquifers. Based on the well depths of (1) up to 30 m depth below ground level, (2) below 30 m, which assumes that the take is from a deep aquifer that is overlain by an aquitard (a partially restricted layer) and an upper aquifer. An associated model was developed to estimate storativity and transmissivity for areas where information is not available, using a random forest machine learning approach. The research team is working to apply and test the model with Waikato Regional Council in the Hauraki catchment, and Environment Canterbury in the Ashley River catchment. [Channa Rajanayaka, Doug Booker, Jing Yang]

Groundwater well drilling in Canterbury

NIWA continues to work with Environment Canterbury, Plant & Food Research, Lincoln University and AgResearch to understand dynamic hydrological processes and contaminant transport in rolling terrain underlain with wind-blown loess deposits. Recently, the research team drilled three groundwater wells to better understand the wider hydrogeological structure around the catchment. Channa Rajanayaka has been working with and advising Environment Canterbury and the wider research team on well drilling and groundwater modelling tasks and designed the locations of the wells to optimise the information that can be gained from wells. The research team investigated the well soil-cores in detail (pictured below) to develop the conceptual understanding of the hydrogeology. [Channa Rajanayaka, MS Srinivasan, Jim Griffiths]




Inspecting drill core in Canterbury yielded much for discussion (Photos: MS Srinivasan, Channa Rajanayaka/NIWA)

Describing River Physical Characteristics

NIWA's 'Physical Characteristics' research project focuses on quantifying the effects of water use schemes (e.g., flood harvesting) and regional water management plans on the physical characteristics that may impact river habitat and physical drivers of ecosystems. The approach typically taken when assessing the effects of a given flow scenario on instream biota is to develop a hydraulic model for the flow scenarios in question and assess habitat suitability using a weighted useable area approach based on habitat suitability criteria (which are based on depth, velocity and substrate). However, not all biota have established (or reliable) habitat suitability criteria and we know that it is not just depth, velocity and substrate that determine biophysical values in a river. As part of this project NIWA outlined the range of biophysical values identified that should be considered when assessing the effects of a change in flow regime; a range of potential objective measures (metrics) that can be used to assess how well a particular value, or range of values, is supported by a given flow; and described how the metrics can be generated and presented to assess the benefit of a given flow. [Jo Hoyle, Richard Measures, Arman Haddadchi, Kathy Kilroy, Kristy Hogsden, Rik Stoffels, Amy Whitehead].

Drone Flow

NIWA will produce a field guide for measuring river discharge from the air with drones and cameras. The advice document will specifically focus on conversions from surface velocity to depth averaged velocity and will leverage breakthroughs from the 'drone flow' research programme. This project will work with key stakeholders at Tasman District Council, Auckland Council, Taranaki District Council and Environment Southland. This project strengthens NIWA's network of international collaborators including the Hydro Technology Institute Ltd (Japan). [Hamish Biggs, Graeme Smart, Dave Plew, Evan Baddock, Alec Dempster, Hamish Sutton]

Mekem Strong in Solomon

NIWA recently provided advice on water resource availability to Mekem Strong Solomon Islands Fisheries (MSSIF). A desk-top review and analysis were performed to identify potential water sources. As field data was in limited supply (and site visits still out of the question) a mix of satellite data (ASTER) and data from previous feasibility studies were used to identify optimal locations for development of reliable water supply according to the specified criteria. Locations for future hydrological survey were also identified from satellite imagery [Jim Griffiths, Graham Elley].

3-month workshop

Most impacted by international travel restrictions were a group of visitors from India who were visiting NIWA in Christchurch for a three-week hydrological training workshop. Unfortunately, the group were obliged to stay longer than they had initially envisaged as international lockdowns forced them to extend their visit by another 10 weeks in total. Their spirits remained high however, as they were ably assisted by Graham Elley, Evan Baddock, Marty Flanagan and MS Srinivasan.

Staff News

Daniel Collins left NIWA's Hydrological Processes group to return to study at Lincoln University. Kelsey Montgomery remains on maternity leave after the birth of her son, Teddy. Kyle Rasmussen, a student from the University of Colorado, visited during July to work on validating remotely sensed snow cover with observations from NIWA's high-altitude Snow and Ice Network (SIN).

UPDATE

Conny Tschritter

GNS Update

Water dating lab upgrade

The Water Dating Laboratory has upgraded the existing gas chromatograph with a new Plasmadetek emission detector to increase neon and argon detection measurement sensitivity in water samples. The new detector allows for a 20-fold increase in sensitivity and will enable us to collect smaller samples, and the ability to use more robust, smaller flasks which can be posted out to water managers, rather than requiring an onsite visit by GNS Science. Neon was difficult to detect on the previous system with low sensitivity contributing to analytical error.

A further upgrade is planned for next year with the commissioning of a new quadrupole mass spectrometer This machine will primarily be used to undertake selective detection and analysis of noble gases.

Next workshop for the Envirolink Tools project: A Collaborative Satellite Data Workspace for Regional Councils

This project aims to develop a suite of standard processing methods that apply satellite data to identify and map land, soil, vegetation and inland water consistently across New Zealand. The suite employs the Google Earth Engine (GEE) cloud-computing service for satellite data processing, where methods are easily shared between regional councils.

The next workshop will be on 10 December 2020 at the University of Auckland (Covid-19-dependent), and also available as an online webinar. This is the third of four free of charge workshops for regional council and central government staff.

Please register your interest by clicking on this link.

As communicated in the previous workshops, each subsequent workshop contains an increasing amount of regional council participation. We anticipate the next workshop having at least 50% presented by regional council scientists. We have actively engaged with some of you, but if there is any interest to present some of your findings, please get in contact with us.

If you have not participated in the first workshop: not a problem! Let us know through the registration link, and we will get you up to speed via parallel sessions.

Roadmap to Groundwater Quantity Allocation for the West Coast Region (Envirolink Grant)

This project developed a roadmap to introduce a groundwater allocation framework for the West Coast region. The proposed roadmap was based on a literature review of the current regulation, including the new National Policy Statement for Freshwater Management (NPS- FM 2020), and on the water allocation frameworks of ten other NZ regional councils. It includes two major components (Figure 1): (i) a science component that delineated groundwater management zones (GMZ), assessed the connectivity of groundwater to surface water bodies and identified relevant management targets for these GMZ; and (ii) a policy component that developed relevant groundwater management policies for these GMZ in collaboration with the community.

The roadmap methodology was developed to be consistent, transparent and reproductible across the region. The next steps include the development of a case study in the upper Grey River Freshwater Management Unit, as part of a second study commissioned by the Envirolink Scheme.

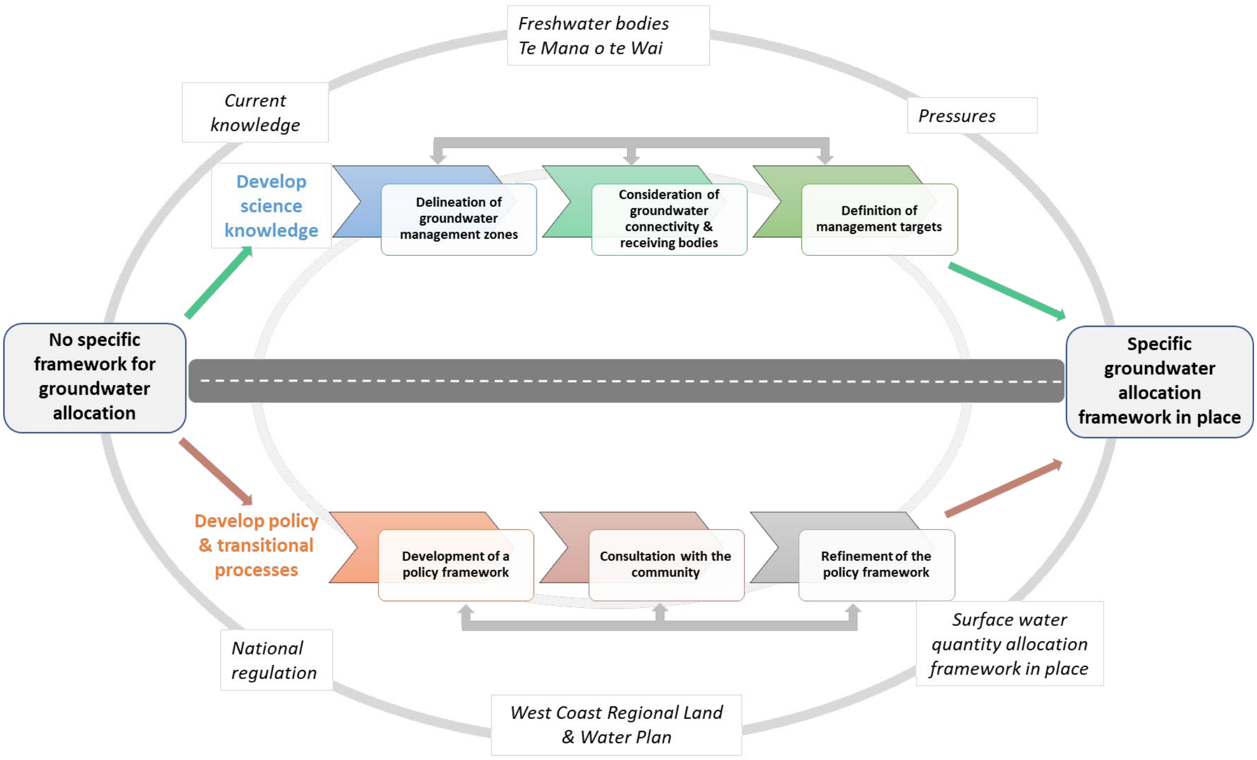


Figure 1: Schematic of the proposed roadmap to groundwater quantity allocation for the West Coast region (Mourot and White, 2020). (GW: Groundwater; LU: Land use; GMZ: Groundwater management zone).

For more info contact Frederika Mourot

Mourot F, White PA. 2020. Roadmap to groundwater quantity allocation limits for the West Coast region. Lower Hutt (NZ): GNS Science. 99 p. Consultancy Report 2020/92.

Zero Carbon Bill & the Effects of Afforestation on the Water Cycle (GNS Science capability development fund)

A growing number of afforestation programmes have been launched worldwide to mitigate carbon emissions. These programmes, if not planned carefully, can lead to unintended consequences on aquatic ecosystem services. Our research investigates the impacts of the New Zealand (NZ) One Billion Trees (1BT) Afforestation Programme on groundwater resources.

The purpose of this project was to develop awareness amongst water, forest and climate actors, and to provide them with insights to inform the sustainable management of the water resources, as a preamble of the research needed in this field in NZ.

In our approach (Figure 2), we used remote-sensed imagery and the processing services of the free cloud-computing satellite data platform Google Earth Engine to:

- Assess the 2018 forest cover and changes between 2000/2001 and 2018, using both global and national datasets;
- Assess groundwater recharge under various afforestation scenarios, building on past forest cover changes, on the 1BT Programme characteristics, and on the NZ National Groundwater Recharge Model.

Results will be presented at the NZHS2020 Conference (1 - 4 December, Invercargill).

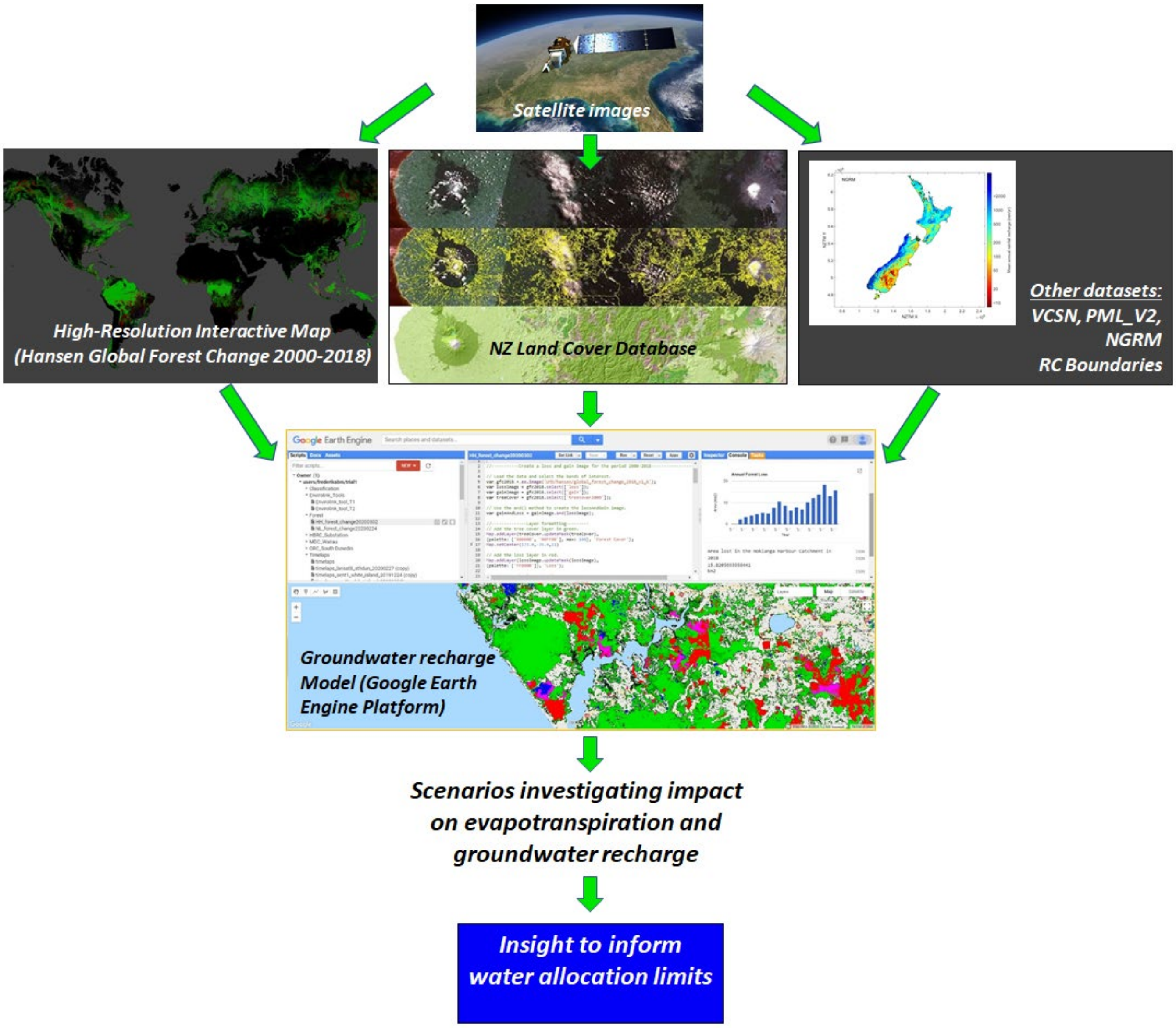


Figure 2: Schematic of the project workflow. (VCSN: Virtual Climate Station Network; PML_V2: Penman-Monteith-Leuning Evapotranspiration V2; NGRM: National Groundwater Recharge Model).

For more info contact: Frederika Mourot.

For more info on the NZ National Groundwater Recharge Model contact: Rogier Westerhoff.

Mourot F, Westerhoff RS, Cameron SG. 2020. Effects of afforestation on groundwater recharge: Perspectives for New Zealand in relation to the One Billion Trees Programme. Lower Hutt (NZ): GNS Science. 96 p. (GNS Science report; 2020/21). doi:10.21420/5ZCK-DJ09

Monitoring the Freshwater Benefit from Management Actions

The recent National Policy Statement for Freshwater Management (NPS-FM, 2020) revolves around the fundamental concept of Te Mana o Te Wai, the fundamental importance of freshwater and the need to sustain itself and its living ecosystems. The NPS-FM requires that the quality of freshwater be maintained, or improved where it is degraded, and introduces additional monitoring and reporting requirements. In this context, land stewards need to be confident that their actions will be effective. Water stewards also need confidence that improvements in the state of our freshwater resource are identified robustly and in a timely manner, and that causal links can be established between management actions and freshwater outcomes.

In partnership with central government, the Our Land and Water (OLW) National Science Challenge (Toitū te Whenua Toiora te Wai) has identified critical knowledge gaps in the design of environmental monitoring capable of verifying the impact of management actions as well as the most appropriate technologies for monitoring the impact of those actions. To address these gaps, OLW has instigated three working groups (WG) within the 'Future Landscapes' Theme. Results of our projects will be used to inform future OLW projects.:

'WG1: Monitoring Design' will develop a "Monitoring Design Framework" and test it in a small number of catchments. It is envisaged that the Framework will be based on a decision support system with associated background information. The project's focus is monitoring on the ground management actions (both on land and within the waterbodies) and their effectiveness at improving freshwater outcomes.

'WG2: Monitoring Technologies' will make a comprehensive inventory of available current and future technologies that can be applied to monitor freshwater quality and quantity; and design that inventory such that it is searchable and updateable, so councils can continue using it after the lifetime of the project.

'WG3: Māori Knowledge Systems' aims to conceptualise Te Mana o Te Wai into the frameworks and technologies of the other WG and give a broader overview of the meaning of Te Mana o Te Wai from the iwi and hapū perspectives. It will provide options for embedding matauranga māori into assessments of water wellbeing within regional decision-making frameworks, including opportunities to improve technology use in assessment processes.

Two working groups (WG1 and WG2) have already started and share a project timeline of July 2020 – February 2021. WG3 is due to start before the end of the 2020 calendar year.

Presentations on all three working groups will be given at the NZHS, NZ Rivers Group & NZFSS Joint Conference in Invercargill: Wednesday 2 December, 3:20-3:50pm; session 32) Policy Implementation. For latest programme: https://www.nzhsrivers2020.co.nz/programme.

One of the inputs we require is your opinion on what freshwater attributes are vital to monitor the freshwater benefit from mitigation actions. We invite everyone to fill in this 2-minute survey:

https://www.surveymonkey.com/r/freshwater_attributes

For more info contact:

Olivier Ausseil – Lead WG1
Rogier Westerhoff – Lead WG2
Tina Porou – Lead WG3
David Houlbrooke – OLW Theme Leader

Dunedin groundwater study update

A new report on groundwater in Dunedin has been published by GNS Science, with co-authors from Otago Regional Council and University of Otago. A network of 23 piezometers was installed in the low-lying coastal area of Dunedin during early 2019. The report provides an overview of observations and shallow groundwater behaviour during the first year of monitoring. It includes interpolations and spatial models of the water table, its response to rainfall and tidal events, shows the degree of saline incursion, and provides geometric models of what might be expected as sea level rises. There are at least five independent lines of evidence that the estuarine and marginal-marine sediment beneath much of the city has low transmissivity and that horizontal and vertical flux of groundwater is small. This provides a good news story for a community seen as extremely vulnerable to effects of sea level rise and surface flooding. It suggests that there will be fewer immediate effects of sea level rise on groundwater than if the ground had high-permeability with extensive tidal flow of seawater in and out of the shallow sediment – as had been widely rumoured prior to the study. Relatively small investment of a network to monitor Dunedin's shallow groundwater appears to have been very worthwhile, enabling planners and engineers to consider a wider range of potential mitigation solutions. The report can be downloaded from the GNS Science webshop for free https://shop.gns.cri.nz/sr_2020-11-pdf. For more information, please get in touch with Simon Cox.

UPDATE

Juliet Clague

Lincoln Agritech Update

The Environmental Research team at Lincoln Agritech has recently welcomed two new staff members, although Antoine Di Ciacca, taking up the Post Doc position in the Braided Rivers Programme, is still in France, awaiting border restrictions to be eased. James Owers has joined the team as a technician in the Hamilton office, relocating from Christchurch. The team has been particularly busy with fieldwork, catching up on time lost during lockdown.

Understanding the nutrient and flow contributions of different sub-catchment

The MBIE-funded Critical Pathways Programme (CPP) aims to unravel the different pathways of contaminant transfer at the sub-catchment scale. Our two study catchments are the headwaters of the Piako, and the Waiotapu stream catchment. In order to achieve an understanding at the sub-catchment scale, we have recently carried out flow gauging in the Wharepapa and Kopuhurihuri sub-catchments in the Waiotapu catchment (Figure 1). Flow gauging has also been done again across the whole of the Upper Piako catchment. In addition to discharge measurements, field parameters (DO, EC, pH and temperature) were also measured, and samples taken for a wide range of analytes including nitrate, forms of P, and tritium.

Figure 1: James Owers carries out flow gauging of the Wharepapa stream sub-catchment in the Waiotapu stream catchment August 2020.

In order to better monitor flow dynamics in various parts of the stream networks, pressure sensors have been installed at key locations in both catchments. They will be gauged periodically to develop rating curves that describe the relationship between water level height and discharge (Figure 2).

Figure 2: A pressure sensor has been installed in the vertical PVC pipe to continuously record water levels while Aldrin Rivas performs a flow gauging to form a relationship between the water level data and discharge.

A lack of reliable meteorological data for our study catchments has necessitated the installation of several dedicated climate stations (Figure 3). The new data on the spatial variation in rainfall and evapotranspiration within our catchments will subsequently feed into our hydrological models.

Figure 3: Climate stations have been installed in both study catchments

So far, continuous flow recorders and nitrate sensors have been installed at two of the four sub-catchment outlets (Figure 4).This high-resolution data will help us understand the relationship between flow and nitrate concentrations and how they change over time.

Figure 4: Continuous flow via a radar sensor and continuous nitrate using a TriOS NICO sensor have been installed at two locations in our upper Piako study catchment.

We have recently had four 50m deep boreholes drilled and groundwater monitoring wells installed, 2 in each of the study catchments. The primary purpose was to gain detailed lithological information at key locations to help interpret the SkyTEM data collected in February 2019. Preliminary results indicate that changes in resistivity in the SkyTEM data correlate well with changes in lithology. The wells will also be sampled periodically to inform our understanding of the deeper groundwater conditions in each catchment.

Figure 5: A 50 m deep borehole was drilled to gather detailed lithological information at 2 locations in each study catchment to cross reference with the SkyTEM data collected in 2019.

Make a note in your diaries: LuWQ 2021 has a new date!

While it seems inevitable that participation by New Zealanders will be much lower than in previous years, if feasible at all, here's a note on the new date for LuWQ2021 in Maastricht:

International Interdisciplinary Conference on Land Use and Water Quality Agriculture and the Environment
Maastricht, the Netherlands

Now scheduled for:
13th – 16th September 2021
Abstracts due by 8th Feb 2021

www.luwq2021.nl

AquiferWatch

Lincoln Agritech and TU Dresden in Germany have developed AquiferWatch, a web-based groundwater forecasting tool which has been trialled in Marlborough. The tool provides daily updates on the state of the unconfined Wairau Aquifer and issues forecasts of groundwater heads and abstractable storage under drought conditions when management of groundwater resources is most challenging. For more information use the QR code or web link below. The maths underlying the tool was developed in collaboration with ESR and is reported in the following publication: Wöhling T & Burbery L (2020). Eigenmodels to forecast groundwater levels in unconfined river-fed aquifers during flow recession. Science of the Total Environment, 747, 141220.

AquiferWatch – Online

aquiferwatch.hydro.tu-dresden.de

Recent publications:

Wöhling T., Burbery L. (2020). Eigenmodels to forecast groundwater levels in unconfined river-fed aquifers during flow recession. Science of the Total Environment, 747, 141220, https://doi:10.1016/j.scitotenv.2020.141220.

Wöhling T., Wilson S.R., Wadsworth V., Davidson P. (2020). Detecting the cause of change using uncertain data: Natural and anthropogenic factors contributing to declining groundwater levels and flows of the Wairau Plain Aquifer, New Zealand. Journal of Hydrology: Regional Studies, 31, 100715, https://doi:10.1016/j.ejrh.2020.100715.

Woodward, S. J. R. and Stenger, R. (2020) Extension of Bayesian chemistry-assisted hydrograph separation to reveal water quality trends (BACH2). *Stochastic Environmental Research and Risk Assessment*, https://doi.org/10.1007/s00477-020-01860-7.

Rivas, A., Barkle, G., Stenger, R., Moorhead, B. Clague, J., (2020) Nitrate removal and secondary effects of a woodchip bioreactor for the treatment of subsurface drainage with dynamic flows under pastoral agriculture. Ecological Engineering 148 (2020) 105786. https://doi.org/10.1016/j.ecoleng.2020.105786.

Maxwell, B., Birgand, F., Schipper, L., Barkle, G., Rivas, A., Helmers, M., and Christianson, L. (2020). High-frequency, in situ sampling of field woodchip bioreactors reveals sources of sampling error and hydraulic inefficiencies. *Journal of Environmental Management* 272, 110996. https://doi.org/10.1016/j.jenvman.2020.110996.

McDowell, R.W., Depree, C., Stenger, R. (2020) Likely controls on dissolved reactive phosphorus concentrations in baseflow of an agricultural stream. *Journal of Soils and Sediments* https://doi.org/10.1007/s11368-020-02644-w.

UPDATE

Helen Rutter

Aqualinc Update

The COVID19 pandemic and lockdown has been an interesting time for many people. It has brought challenges and opportunities that couldn't be foreseen. Within Aqualinc, what had been a quiet start to lockdown, ended up being a busy end. Some of our current projects are covered below.

Aqualinc has had two new projects funded through MPI's Sustainable Land Management and Climate Change (SLMACC) programme, both of which are now underway.

The first of these is a two year climate adaptation project: Agile, Adaptive Water Allocation Policy. The project responds to the challenge that current water allocation methods are likely to become less fit for purpose as the climate changes. It will investigate allocation methods that enable timely adaptation to climate change, with a low transition cost, while delivering the values-balance that society expects.

With input from NIWA and Environment Canterbury, we will use existing climate projections with new modelling of river flows, irrigation demand, drainage fluxes, groundwater levels and lowland stream flows in Central Canterbury to improve understanding of the effects of climate change on flow regimes and water levels.

From here, we will then iteratively re-design and test (using our existing MODFLOW integrated groundwater surface water model of the Selwyn-Waihora water management zone) potential water allocation policies to achieve the level of policy agility required to successfully adapt to climate change. This will include addressing the unsolved problem of how to manage groundwater takes so that the depletion effect they have on connected surface water bodies does not cause surface-water allocation limits to be exceeded.

The second project, funded under the Freshwater Mitigation category of SLMACC, is a four year field trial of N-Wise irrigation management strategies. This builds on previous computer modelling in projects for the Fertiliser Association of New Zealand, which has shown that by changing irrigation management practices an average 27% reduction in modelled nitrogen loss to water is achievable, with minimal impacts on average annual pasture production. The new project will field test the performance of N-Wise irrigation strategies on a commercial dairy farm in Canterbury under realistic conditions of water supply uncertainty.

We are partnering with DairyNZ and we will be communicating the "what, how and why" of N-Wise Irrigation to Canterbury dairy farmers as the field-trial progresses.

Establishment of the field site is underway: a climate station has been installed, and 18 GroundTruth lysimeters (each with telemetered soil moisture monitoring) are under construction in conjunction with Samuel Dennis from Grounded Ltd. Keep an eye out for further updates as the field trials get underway.

N-Wise irrigation management strategies

On a smaller scale, a short turnaround project for us, has been the irrigated area mapping project for MfE, which comprised updating our previous mapping exercise from 3 years ago. This dataset will be available from the MfE website in due course.

In October, Helen Rutter presented the work carried out by Ella Harris (a summer student from last summer), to the Geosciences Society of New Zealand. The background to the work was the acceptance that drillers' logs are vital to understanding the subsurface geology, and are used by hydrogeologists on a daily basis, for developing conceptual models of aquifer systems, developing the framework for 3D numerical models, and for consenting purposes. Appreciating how reliable these data are is critical.

Christchurch City Council had drilled sonic bores to identify the depth to the first aquitard across Christchurch. The sonic core data were compared to existing nearby drillers' logs, through checking the lithology and predominant sediment type at increments of 0.5 m. We found that just over half of the main sediment types were identified correctly in drillers' logs, and there was misidentification in the rest. Whilst most of the misidentification was between different fine-grained sediments, in some cases gravels were described as sands/silts/clays, and vice versa. Clays were found to be very much over-represented in drillers' logs, with most of the clays actually being sands or silts.

An example of sonic 'core' is shown below, which also shows a good example of open framework gravels:

The video from the talk can be seen at https://www.youtube.com/watch?v=iV1ODyHJ4yo.

More generally, the Freshwater Reforms have resulted in updates of the NPS-FM and the NES which set new standards in terms of how freshwater resources are to be managed. We've recently been reviewing these documents to see what will need to change, and we're now assessing consent applications against these documents. There is no doubt that many clients will be impacted by the changes.

We are continuing to work in many different areas of groundwater modelling, including modelling recharge to GW, continuing updating models in the Tasman Region, updating the Canterbury groundwater model, using existing models for delineating source protection zones, and carrying out heat flow modelling for ground source heat pump systems.

With the 2020 winter being in the top 3 for the warmest and driest on record, the Irrigation Management season is already cranking up. There has been a lot of development of the myIrrigation II website, with the recent focus being on speeding up response times. The fact that our clients are actively checking soil moistures and temperatures is a good indication of how dry it is out there this year.

UPDATE

Theo Sarris

ESR Update

Science for Communities

Staffing updates

Allanah Kenny and Mark Flintoft have recently joined ESR's groundwater team. Allanah is currently working as a Groundwater Modeller alongside Theo Sarris and David Scott at ESR in Christchurch. She was previously a Postdoc in the Mechanical Engineering department at the University of Canterbury. Prior to that she completed her PhD in Mechanical Engineering and a MSc in Mathematics specialising in large scale numerical modelling of neurovascular coupling. Mark is a hydrogeologist with over 20 years' experience with interest in contaminant fate and transport, groundwater modelling and groundwater quantity. He is passionate about sailing and a familiar face to ESR's groundwater team, where he worked between 2000 and 2010, before joining Aqualinc.

Allanah Kenny

Mark Flintoft

Groundwater Mitigations Programme

Monitoring and assessment of the performance of the experimental woodchip denitrification wall in the gravel aquifer at Silverstream Reserve has continued under ESR's Groundwater Mitigations research project. **Phil Abraham, Richard Sutton** and **Panan Sitthirit** have been conducting routine field-sampling of groundwater for chemical and microbiological analysis, as well as making measurements of greenhouse gas emissions at the site. The wall is coming up to its second anniversary and continues to demonstrate effective removal of nitrate in groundwater at the field site. A suite of hydrogeophysical experiments to determine the hydraulic function of the woodchip wall commenced after COVID-19 lockdown restrictions were lifted, the results of which are currently being analysed. **Louise Weaver** and **Judith Webber** are analysing the environmental DNA data collected from the study site, whilst **Annette Bolton** analyses macrofauna. From these the microbial function of groundwater remediation system will be characterised. The denitrification wall project itself has been sort-listed as a finalist for the up-coming Primary Industries NZ Science and Research award.

Figure 3. Phil Abraham and Panan Sitthirit collecting biobags for DNA analysis at Silverstream Reserve

Also, as part of the same project, **Richard Sutton** is keeping busy, maintaining a lab experiment comprising 39 flow-through columns in which methane-induced denitrification is being tested.

Meanwhile, **Phil Abraham** has been working on instrumenting the in-stream woodchip denitrifying bioreactor installed on a dairy farm near Geraldine for automated monitoring. Both NIWA and DairyNZ are co-supporters of the project that is aiming to assess the viability of woodchip denitrifying bioreactor technology as a nitrate-mitigation tool in the Canterbury landscape. Phil has also been maintaining the autonomous groundwater nitrate monitoring stations ESR has established in the Silverstream catchment, North Canterbury where real-time groundwater nitrate measurements have bene made daily since 2018. The continuous, high frequency monitoring data are revealing some interesting information on surface-water groundwater interactions in the catchment where nitrate pollution is an issue.

References:

Burbery, L.F. et al. Woodchip denitrification wall technology trialled in a shallow alluvial gravel aquifer. *Ecological Engineering 157 (2020) 105996.*

Burbery, L.F., Abraham, P.M., Woods D. South Canterbury Deep Groundwater Investigation (revised 2020). ESR Report #CSC15006, prepared for Environment Canterbury.

Wöhling, T. and Burbery, L.F. Eigenmodels to forecast groundwater levels in unconfined river-fed aquifers during flow recession, *Science of the Total Environment* (2020),

Novel DNA tracers for tracking water contamination

We have completed a MBIE Smart Idea Fund project on the development of synthetic DNA tracers for tracking water contamination. A suite of 20 different DNA tracers are now available, either as free form or encapsulated within microparticles of food-grade biopolymers. In collaboration with Environment Canterbury and Waikato Regional Council, proof-of-concept field validations in groundwater, surface water and soil systems showed promise, and DNA tracers were trackable in a stream for at least 1 km. We will continue to work with end users to upscale the technology in field conditions. DNA tracer techniques have a bright future as new tools that can concurrently track multiple pollution sources and pathways in freshwater environments and facilitate hydrological investigations in complex natural environments and engineered systems. Contact **Liping Pang** for more details.

References:

Pang L, Abeysekera G, Hanning K, Premaratne A, Robson B, Abraham P, Sutton R, Hanson C, Hadfield J, Heiligenthal L, Stone D. 2020. Water tracking in surface water, groundwater and soils using free and alginate-chitosan encapsulated synthetic DNA tracers. *Water Research.* 184:116192.

Bridging the gap in OWMS performance: a field scale model

In partnership with Environment Canterbury and Hynds, **Louise Weaver, Bronwyn Humphries** and **Lee Burbery** are working on a project that will evaluate the performance of a model operational On-site Wastewater Management System (OWMS) and quantify its impact on the receiving groundwater environment. The project aims to provide a practical case study that will examine the process of design, installation, operation and environmental assessment of OWMSs. The treatment performance offered by various staged components of the OWMS are to be studied and assessed against assumptions made in Regional Plan regulations. OWMS design engineers Andrew Dakers and Fiona Ambury have assisted with the experimental design stage. In October, the first stage of field investigation was completed: using the services of Southern Geophysical Ltd, time-lapse electrical resistivity tomographic methods were applied to predict where the effluent plume from the planned Land Application System will migrate to and thus inform design of a monitoring well network.

Pathogen removal in water filtration systems using micro mimics

Using a novel surrogate technique and pathogen testing in pilot-scale experiments, we determined the efficacies of protozoan and virus removal by drinking-water filtration systems commonly used in New Zealand under typical operating conditions. These included rapid sand filtration systems using a pilot plant at Invercargill Water Treatment Plant and point-of-use domestic filters. The experimental findings were incorporated into quantitative microbial risk assessments and cost-benefit analyses. Health-risk scenarios were identified and recommendations for improving treatment performance provided. Contact **Liping Pang** for more details.

UPDATE

NZHS Administration

Oxfam Update

OXFAM

The New Zealand Hydrological Society is proud to announce our latest partnership with Oxfam through a financial contribution to the FLOW project.

FLOW is Oxfam's latest four-year project based in the Henganofi district, Eastern Highlands of Papua New Guinea (PNG). FLOW officially started in June 2019 and is set to finish around June 2023.

FLOW stands for Fostering Lasting Opportunities in WaSH and WaSH stands for Water, Sanitation, and Hygiene.

FLOW's overarching goal is to improve health, resilience, and quality of life for remote and vulnerable communities, particularly women and children, in rural PNG. It aims to do this by:

- Enhance reliable WaSH infrastructure by improving/installing water supply systems and sanitation infrastructure in 12 schools and eight health centres.
- Improve hygiene practice, including menstrual hygiene management, by delivering hygiene packages, and conducting training sessions in schools and health centres.
- Increase the knowledge and understanding of good health and hygiene practices by supporting the PNG government to implement the WaSH policy, and to motivate communities to demand the rollout of WaSH related services.

Follow this link to read the 1st FLOW Project Report July 2020.

The report looks at the insights, highlights and challenges from the first 6 months of the project. Despite the unprecedented times that we all continue to face; so much positivity and progression has already been achieved with partners and communities in PNG...and this is just the beginning.

The first half-yearly report of the FLOW project. Next page: Some images from the report.

Photo: Belinda Bradley/Oxfam

A gift from Oxfam and a note to you, the NZHS membership

Kia ora NZHS – members and employees alike! We wanted to send a token of gratitude for your support of the wonderful 'FLOW' project in Papua New Guinea.

Last year 'Misery', an NZ muralist and artist – joined forces with Oxfam NZ – to create a one-off mural. She painted it live on Queens Street to raise awareness for the FLOW programme, as well as funds. Enclosed is a print-version of her beautiful artwork! We hope this will serve as a lovely (colourful!) addition to the office and a special reminder of your involvement in this life-changing work.

We are so happy to have you with us on this journey. Sending warm wishes to you.

Nga mihi nui,

Bryony and the Oxfam New Zealand team.

WEATHERING THE STORM

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