Extreme rainfall – forest flows The need for water resilient landscapes

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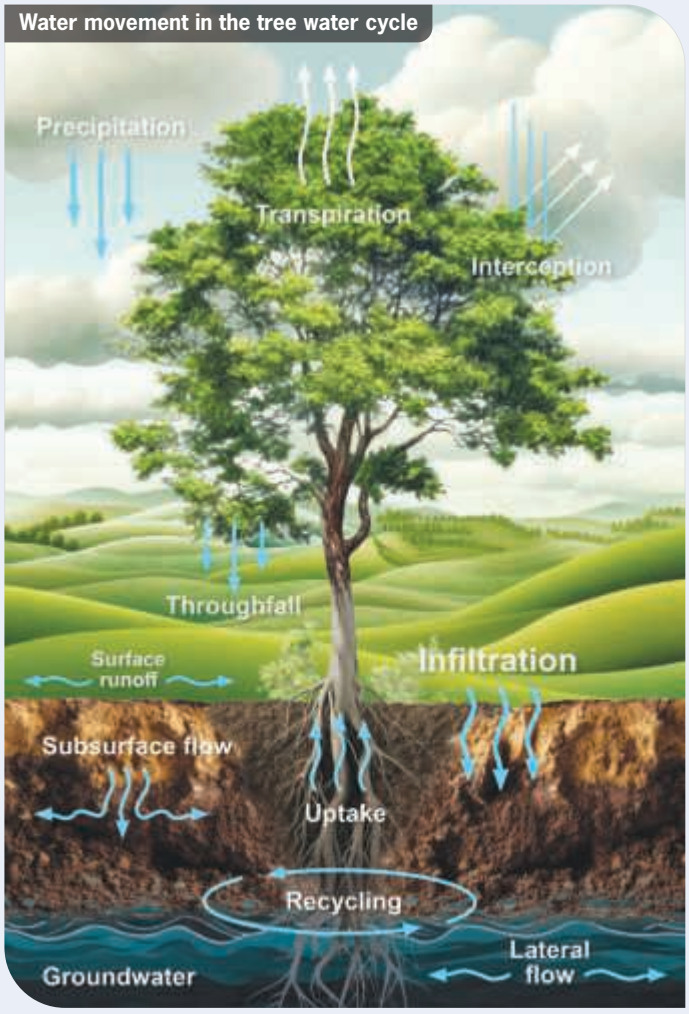
Extreme weather is becoming more common. Knowing where the water is, where it is going and who gets to use it are the three main questions which the forest flows researchers aim to answer.

Now more than ever, New Zealanders are looking for answers about the environment we live in. How do we use our natural resources in the most sustainable way in the face of a changing climate?

Water is one of our most precious taonga and this resource is increasingly put under pressure due to climate change and land use intensification. The Scion Forest Flows research programme, funded from the Ministry of Business, Innovation and Employment Endeavour fund, is investigating how we can create and maintain water-resilient landscapes to provide benefits for all New Zealand.



The Forest Flows programme has developed a new, integrated method of terrestrial and remote sensing to quantify processes in tree water use, water storage and release from planted forest catchments. Biophysical results and community involvement have provided new information for end users to assess the combined social, ecological and economic implications of land use decisions on the provision of water services. The new model will accurately predict water storage and release over entire forest catchments and also provide data on changes in water quality.

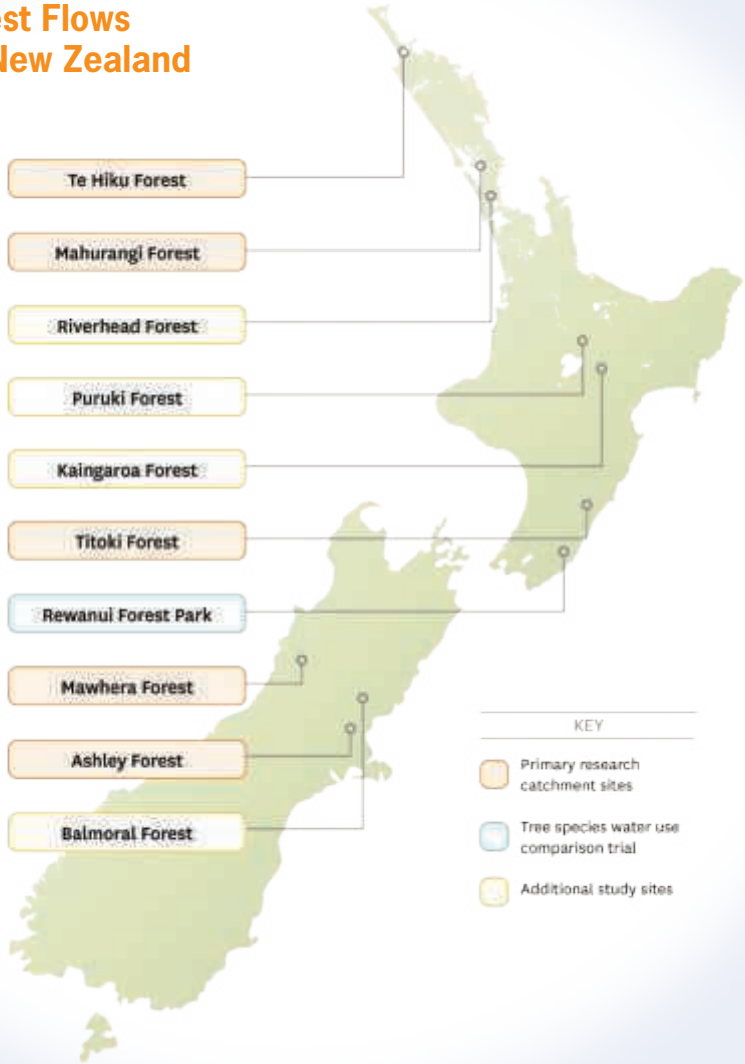
Forest Flows

Forest Flows is the five-year $13.7 million research programme, which uses a network of over 1,700 sensors in 10 forests across the country. The sensors record data every five minutes. The research programme is in its fourth year and preliminary results from extreme rainfall are now available. Programme leader and senior scientist, Dean Meason, in collaboration with NIWA, analysed data from the floods during the Auckland Anniversary weekend and from Cyclone Gabrielle

Data from the ground-based sensor networks provided, for the first time, direct measurements from sensors continuously recording data at five-minute intervals. Rainfall, soil moisture, stream flow and groundwater recordings have been used to create a picture of where the water went during and after these storms. Two of the five primary research catchment areas, located in Mahurangi Forest in the Auckland region and Titoki Forest in the Tararua district, experienced the worst of the extreme storms in 2023.

Despite extraordinary levels of rainfall over 60 hours over Auckland Anniversary weekend, and although the

Location of the ten Forest Flows study sites throughout New Zealand



soil is shallow at the Mahurangi and Titoki sites, it did not reach saturation point.

These small research sites are on erodible soils in planted forest catchments of radiata pine but are representative of much larger areas. These sites showed little evidence of small-to-medium hillslope failures or slips and woody debris movement from side slopes.

Sample plots

Plots were established within each catchment to measure above and below the ground. Topographic, wind and soil features at randomly selected locations within each catchment provided a representative spread across the catchment. Permanent sample plots 20 metres by 20 metres were established by Scion technicians.

Above ground attributes recorded in the sample plots include diameter at breast height, tree height, canopy density, terrain conductivity and leaf area index. Below ground attributes were measured in partnership with NIWA. These include taking soil samples to measure the age of the soil water and soil texture, three-dimensional soil texture mapping, ground penetrating radar and monitoring shallow ground water. Scion also installed six different sensors as part of the core the sensor network. These include dendrometers, soil moisture sensors, potentiometers, sap flow meters, stream nitrate sensors and lysimeters.

Rural communities surveyed

Earlier in the programme, in August 2022, we conducted a telephone survey of three rural communities in Far North, Tararua, and Wairarapa districts. The survey was conducted by Research First on 363 farmers and lifestyle block owners. The survey helped establish a baseline of perspectives from these communities on water use and trees on farms.

Estimated water balance for the Mahurangi Forest research catchment								
Hyetograph		Hydrograph		Evapotranspiration	Ground water	Run-off	Evapotranspiration	Ground water
Hours	mm	Hours	mm	mm	mm	Per cent	Per cent	Per cent
30	229	65	91.3	2.9	134.9	40	1	59

Mahurangi Forest catchment

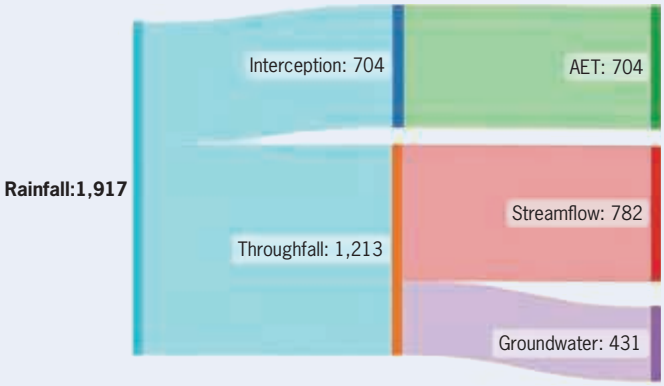
Mahurangi Forest is located north of Auckland. The forest consist of radiata pine and the stand is mid rotation. Within Mahurangi Forest, the Forest Flows primary catchment is a 36-hectare catchment where the team established 25 sample plots.

The catchment was selected due to its ease of access. Additionally, there were no plans by Matariki/Rayonier to harvest this catchment during the lifetime of the project and the stream running through the catchment has regular flow during most months.

During Auckland Anniversary weekend in January 2023, the Mahurangi Forest catchment received 229 mm of rain. Throughout the main event, 59 per cent of that rainfall was retained in the catchment as groundwater rather than flowing immediately downstream. Contrary to what is commonly believed, we demonstrated that the soil near the surface did not saturate.

Soil moisture sensor at Mahurangi forest

Annual water balance January to December 2022 at Mahurangi Forest



Hydrological data at four of the Forest Flows monitoring sites has been analysed for monthly water balance estimates, which can be used to demonstrate an annual water balance. The diagram above shows the water balance at the Mahurangi Forest site from January to December 2022. The left side of the diagram is the water entering the catchment from rainfall and the right side of the diagram explains the components for water leaving the catchment. Generally, water moves into groundwater or into streams and even at drier sites, the majority of water is not used by the trees.

Titoki Forest Falls Block catchment

Titoki Forest Falls Block is situated 55 kilometres east of Dannevirke in the lower North Island. The primary catchment area is 60 hectares and was the last of the five primary catchments to be established. This catchment was selected due to its size and it was less complex compared to the others. This site was selected as there was an increased concern that farmland was being converted to radiata pine plantations which would reduce water availability to downstream users. This study can help councils and land owners understand the role pine plantations play in managing water, particularly for downstream users.

These results, as well as further analysis, will boost our understanding of the site conditions that lead to catastrophic landslides and flooding in forest catchments so authorities and the forestry sector can mitigate any negative downstream effects.

Estimated water balance for the Titoki Forest research catchment from cyclone Gabrielle								
Hyetograph		Hydrograph		Evapotranspiration	Ground water	Run-off	Evapotranspiration	Ground water
Hours	mm	Hours	mm	mm	mm	Per cent	Per cent	Per cent
24	78	24	31.6	8	38.4	40.5	10.3	49.2

More results still to come

The research teams are busy analysing the large amount of data generated so far. Programme results are expected in mid-2024 and we will be closer to answering where the water is, where is it going and who gets to use it. Water quality, nitrate flux, water storage, and variations across and within catchment sites will all feature in the results.

Early results from the new biophysical model look very promising with predicted values closely aligning to observed values. Along with extreme rainfall, water resilient climates will need to be able to cope with extreme dry periods. Questions on how much water planted forests use, what happens during drier months and at drier sites, and how much water is stored in planted forest catchments will be considered as well as a better understanding of the reasons for these mechanisms. The water use of indigenous species and exotic species has been investigated and this analysis will be available in 2024.

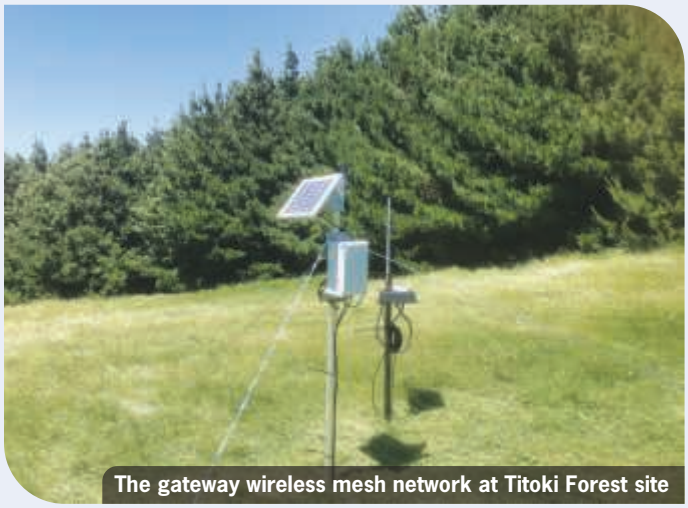
Effect of extreme rainfall

Socio-economic and cultural effects of planted forests is one of the Forest Flows research areas. As this part of the programme has a large policy focus, the team are actively working with regional councils to demonstrate the value of the new biophysical process based model and increased understanding of what happens when a planted forest catchment has a large influx of water during a storm under current and future climate events.

The team are in discussions with Auckland council to provide insight on how Forest Flows results, biophysical model and understanding of extreme rainfall can be used for planning and decision-making. They have also teamed up with the council's catchment group workshop programme, delivered throughout the Auckland region, to share knowledge about hydrology and how grass-roots actions can improve waterways and mitigate the effects of extreme rainfall. The Forest Flows team is also involved with other councils around New Zealand.

Community involvement

Wananga are planned for April and June 2024 to discuss results with local iwi and communities. Scion's leader of the Economy and Society research group Grace Villamor is leading this part of the programme. Regular and active involvement with our communities throughout the final year will help us convey the most meaningful research insights – each group has different values and requirements for information. Rather than dictating what results we believe are important, we aim to understand what is important and valuable to the community and provide them with the answers that they seek.


The gateway wireless mesh network at Titoki Forest site

One invaluable method for working with iwi and community groups is through the use of data visualisation. Working closely with Y5, a software company in the heart of Waikato, the team have created a three dimensiional visualisation of soil water movement through a catchment during rainfall. The user can interact in a number of ways including pausing or fast forwarding the event, finding different depths and a two dimensional cross-section across the catchment between any two points.

Forest Flows is on the home stretch with the programme finishing in 2024. The new biophysical model will be a useful way to accurately simulate many paramaters of tree growth and water use, enabling industry, councils and land owners to make better decisions about land use and water provisions.

Forest Flows is five-year Ministry for Business, Innovation and Employement Endeavour Research programme, led by Scion's Dean Meason.