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Sources and transit times of water in headwater temperate rainforest streams

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Headwater catchments are important sources of water for many river systems. Unlike lower reaches of rivers that are frequently connected to alluvial aquifers, headwater catchments are commonly developed on indurated rocks that lack extensive groundwater systems. The observation, however, that many headwater streams are perennial implies that streamflow is sustained by water contained in fractures, soils, and/or the regolith. Understanding the sources and transit times of water that generates streamflow in headwater streams is important for understanding catchment functioning and predicting the response of catchments to changing climate or land use.

This study determines water sources and transit times in first-order streams from a temperate rainforest in the Otway Ranges, southeast Australia. Comparison of the major ion geochemistry of soil water, water flowing through soil pipes (macropores), and groundwater from the riparian zone adjacent to the stream indicates that water from soil pipes is the major contributor to streamflow. By contrast, riparian zone groundwater and water from elsewhere within the soils contributes little to streamflow. The streams are gaining and the lack of riparian zone groundwater inputs may be due to the presence of low hydraulic-conductivity organic-rich streambed sediments or compartmentalisation of shallow groundwater by clays in the weathered rocks. Similarly, pockets of isolated water within the soils that are not connected to the soil pipes also exist.

The stream water has tritium (^{3}H) activities of 1.80 to 2.06 TU, with slightly higher activities recorded during the higher winter flows. The water from the soil pipes has ^{3}H activities of 1.80 to 2.25 TU, the riparian zone groundwater has ^{3}H activities of 1.35 to 2.39 TU, and one sample of soil water has a ^{3}H activity of 2.22 TU. The ^{3}H activities of all these catchment waters are significantly lower than those of modern rainfall (2.6 to 3.0 TU), and mean transit times calculated using a range of lumped parameter models are between 3 and 57 years. These mean transit times are consistent with the waters being resident in the catchment for sufficient time for weathering reactions and evapotranspiration to occur.

While the discharge from the soil pipes increases following periods of high rainfall, this water is stored for several years within the catchment before discharge (probably within the weathered regolith). Thus, the increase in discharge is not the simple transmission of recent rainfall through the macropores but mobilisation of younger stores of water as the catchment wets up. The long mean transit times of the stream water imply that it is derived from a relatively large store ($>10^8$ m^3) and is buffered against year-on-year variations in rainfall. However, longer-term variations in rainfall or land use will likely impact streamflow.