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Climate change and groundwater - an Australian perspective

Hydrolink

CLIMATE CHANGE AND GROUNDWATER: AN AUSTRALIAN PERSPECTIVE

BY GLEN WALKER, RUSSELL CROSBIE, FRANCIS CHIEW, LUK PEETERS & RICK EVANS

The annual streamflow into water storages of Perth, a major city in south-western Australia, has fallen from 338 giga liters (GL) in the period 1911–1974 to 134 giga liters (GL) during 1975–2017[1]. This loss of surface water inflow, due to a drying climate, has raised awareness amongst water planners of climate change and potential water shortages affecting cities and irrigation areas across southern Australia. This article discusses the role of groundwater in response to climate change in Australia.

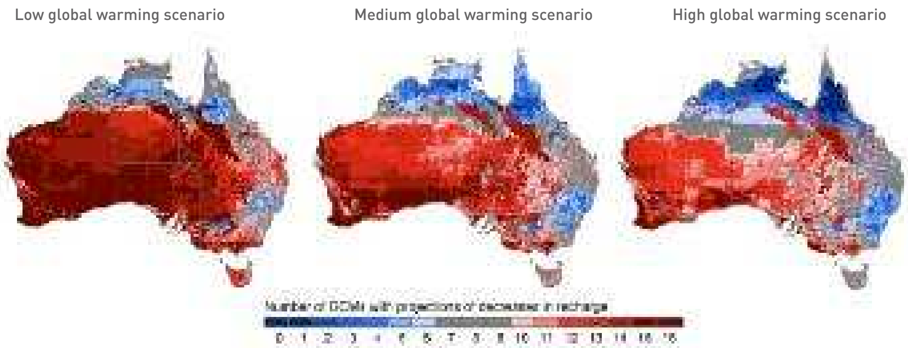

Figure 1. Number of GCMs (general circulation model) under which a decrease in recharge is projected (from the 16 GCMs for each global warming scenario). The consistency of darker reds in the very south for all climate scenarios means greater likelihood of recharge reducing. From [7]

Groundwater is an important source of water in Australia. It represents about 30% of total water use [2] in Australia, and it is the main source or only source of water in drier regions. It is particularly important during droughts, when surface water resources are limited [3]. However, most of the groundwater in the drier areas of southern Australia is too saline for human consumption or irrigated agriculture. Fresher groundwater is heavily used, but is spatially patchy.

Since 1990, water planning in Australia has undergone national reform [4]. Responsibility for water allocation has shifted towards regional authorities, supported by state agencies. There, water planning can be integrated with other planning (such as regional development) and all sources of water (surface water, groundwater, desalination, recycled, imported) considered in relation to changing demands. As demand increases to near the limit of the current water availability alternative and more (climate) resilient supplies and contingency plans need to be developed.

Under the water reform, groundwater is managed to balance consumptive and environmental water requirements to protect important ecosystems. The process differs across and within jurisdictions, but usually involves either the setting of an extraction limit and associated rules for consumptive use, and/or adjustment of allocations based on the state of the ground water system.

The climate projections for Australia [1] show further increases in temperatures; decreases in cool-season rainfall across southern Australia, with more time spent in drought; and more intense heavy rainfall throughout Australia. These predictions reflect recent climatic and hydrological trends. For example, the May to July rainfall across south-western Australia has been reduced by 20% since 1970[1], while projected June to August rainfall in 2090 is 32 ± 11% lower than in 1990[5]. Similarly, the April to October rainfall for 1999-2018 over south-eastern Australia has fallen 11% compared to the 1900-1998 period[1], while the projection for June to August rainfall for the Murray-Darling Basin in south-eastern Australia in 2090 is less than that in 1990 by 16 ± 22%[5]. Despite the large uncertainty in the future projections, there is consistency with respect to the direction of change across the different global climate models for southern Australia. The observed long-term reduction in rainfall has led to even greater reductions in stream flows in southern Australia, as illustrated by the reduced inflows for Perth dams [1] and runoff across Victoria and the southern Murray-Darling Basin [6].
Climate change can affect groundwater directly by changing inflows (such as diffuse recharge, i.e. recharge that occurs by percolation below the rooting zone across the landscape) and outflows (such as evapotranspiration). Climate can also affect groundwater indirectly through changes in other sources of water, land use and demand.

Southern Australia has winter-dominant rainfall, run-off and recharge. Reductions in winter rainfall lead to amplified reductions in diffuse recharge. This means that a reduction of cool season rainfall by 10% may possibly reduce diffuse recharge or recharge by 30% [7]. This causes water planners most concern as moderate reductions in rainfall cause major reductions in groundwater availability.

Diffuse recharge under future climate can be informed by rainfall outputs (long-term averages and high rainfall intensity driving recharge) of global climate models. Since such models do not estimate local climate well, the results need to be downscaled to better reflect future local climate. Physically based soil-vegetation-atmosphere models have been used in Australia to estimate the change in recharge due to changed climate using this down-scaled climate data as input. The uncertainty in each of the models from global climate model to downscaling to recharge models combine to generate a large predictive uncertainty. Recharge outputs will have generally greater

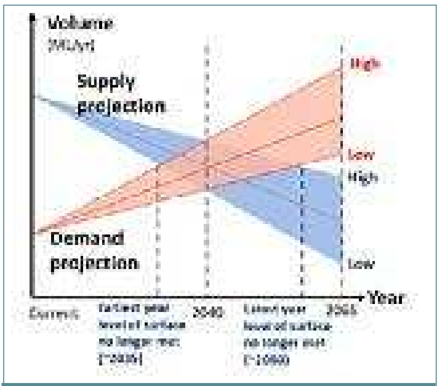

Figure 2. The inclusion of uncertainty into supply and demand predictions, showing how this translates to uncertainty in timing once demand matches supply

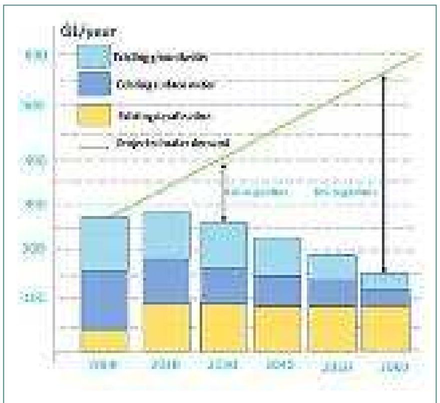

Figure 3. The projections of supply and demand for Perth and surrounding areas until 2060. The supply is separated into groundwater, surface water and existing desalination. Adapted from [12].

variability than surface water run-off outputs due to the nature of the models and the underlying data. There may also be biases introduced by assumptions in the models (e.g. free drainage) which may not hold in the future, and the impact of climate on other recharge factors such as land use and streamflow. While further investigations may reduce this uncertainty, it will never be eliminated. This means that any water resource planning will need to incorporate uncertainty in managing climate change risk.

Information on changes in recharge is available in Australia via maps and associated databases at various scales, for different climate scenarios and using different downscaling and recharge models [7],[8],[9]. Outputs are often depicted in a way to reflect the degree of consistency in predictions (Figure 1). The outputs of both global circulation models and downscaling techniques are also available for use in other models [10].

Despite the large uncertainty in the predictions of recharge, these estimates provide useful inputs to the water planning process [11]. Most planning processes use a risk approach and need to consider a range of recharge outputs, including the worst-case scenarios.
The extraction limit is more directly relevant to the water planning process than recharge, as it represents the maximum volume of groundwater that can be pumped. While a reduction in recharge will generally lead to a reduction in the extraction limit, the relative reduction is likely to be amplified, due to minimum environmental water requirements. The degree of amplification will be influenced by decisions regarding the trade-offs between the economic benefits of consumptive use and adverse impacts on the environment. The extraction limit also depends on the hydrogeology which introduces more uncertainty in its determination.

Because predictions for southern Australian are for further drying into the future, any uncertainty in the extraction limit will affect the rate of decline of supply and hence the time lag before any action to be taken. Uncertainty in recharge can therefore be conceptualized as uncertainty in timing for actions to be required (Figure 2). The timing of any actions also depends on the climate impacts on demand. Demands for water will depend on a range of factors, including population growth and regional development. Climate change may affect demand through changes in the types of irrigated crop, crop water use and dryland vegetation in response to higher temperatures, lower rainfall, lower water reliability and higher water prices. As it could be costly to implement appropriate management responses either long before they are needed or too late, some form of adaptive management is required once demand approaches supply. Even though climate change will have a widespread impact on recharge across southern Australia, the impact on groundwater management will be locally variable. Factors affecting groundwater vulnerability to climate change [7] include ratio of groundwater use to extraction limit and effective aquifer storage. Relatively higher groundwater use means that not only is there minimal opportunity for greater use of groundwater, but a risk that entitlements of groundwater may need to reduce to fall below sustainable levels of extraction. This applies almost exclusively to fresh groundwater systems.

A low aquifer storage means that there is only a small buffer (and hence time) to manage any reduction in recharge. Groundwater systems tend to be more resilient to climate variability because the large aquifer storage can be much greater than dam storages. For this reason, groundwater systems have often been used as a drought contingency measure. Small groundwater systems, such as fresh-water lenses, can be vulnerable during droughts. The effective storage is also influenced by high-value groundwater-dependent ecosystems that require higher water tables to avoid degradation of health and to protect baseflow.

Dr Glen Walker is a groundwater hydrologist, who worked with CSIRO in Adelaide for over 30 years before setting up his own consultancy, Grounded in Water. He specializes in salinity and groundwater sustainability.

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Dr Crosbie is a Principal Research Scientist at CSIRO and is currently the Team Leader of the Regional Scale Groundwater Analysis team. Throughout his research career he has worked in several areas including water resources, climate change, salinity and water in the resources sector. He is best known for his expertise in estimating groundwater recharge, particularly under climate change. He is the author (or co-author) of over 100 scientific publications.

Dr Luk Peeters research focuses on modelling groundwater dynamics at hte regional to continental scales with a focus on the uncertainly of model predications both quantitatively and qualitatively. Luk led the developmentt and application of the uncertainty analysis, including propagation of uncertainty between model, for the Bioregional Assesments Proggram.

Dr Richard Evans is Principal Hydrogeologist with Jacobs. Rick has 40 years experience in all aspects of water resource development with a focus on groundwater resource management and managed aquifer recharge. He has worked on numerous water resource projects throughout Australia and Asia. His strong interest is on the potential for conjunctive water management and managed aquifer recharge to secure both urban and irrigation development throughout Australia.

Should groundwater extraction approach the extraction limit, management responses are similar to those for any stressed system, namely some combination of redistributing extraction through trade; reducing demand; augmenting recharge (through managed aquifer recharge, water sensitive urban design and changing land use) and seeking alternative sources. All of these are used or planned in Australia. The aim of these management responses is to develop a water supply that is more resilient to climate change.

Perth has advanced most with their planning process for climate change impacts. While Perth has declining rainfall, surface water and groundwater, its demand is increasing. A gap has been identified between supply and demand of 120 GL/yr by 2030 and 365 GL/yr by 2060 (Figure 3)[12]. As part of the Water Forever Plan, the gap is to be met by reduction in water use (74 GL/yr by 2030 and another 102 GL/yr by 2060), increased water recycling (39, 48 respectively) and new sources 218, 335 respectively). The new sources of water include managed aquifer recharge, further desalination and deeper groundwater systems [10]. Since its initial release, the plan has continued to change.

Conclusions

While there are potentially other impacts of climate change on Australian groundwater, the drying climate and longer droughts in southern Australia is the most immediate threat. The amplification of reductions in rainfall into reductions in recharge, and then further amplification to reductions in extraction limit mean that groundwater supplies can diminish quickly.

The large uncertainties in climate prediction, together with those of hydrogeology, means that predictive uncertainty is high. An adaptive management strategy is required both for the groundwater supply as part of an integrated water supply, but also the management of the groundwater supply itself. Adaptive management will, in turn, require monitoring of extraction, piezometric responses and land use and more attention to forecasting demand. There needs to be a general shift to more climate-resilient sources of water such as desalination, managed aquifer recharge and water use efficiency measures.

The experience in Perth provides a guide for other regional water authorities in planning for climate change. ■

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