A Framework for Determining Environmental Water Requirements for Alluvial Aquifer Ecosystems

by

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Certification

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

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Abstract

Demand for groundwater is accelerating in Australia and globally. The development of guidelines to ensure ecologically sustainable use of groundwater lags behind this demand, although the broad policy and planning base for environmental water requirements is in place in Australia. Environmental water requirements in aquifers are the groundwater regimes needed to maintain or restore ecological processes and conserve biodiversity. The existing framework for environmental allocations for aquifers requires identification of groundwater dependent ecosystems and estimation of their water requirements in terms of: level (in unconfined aquifers) or pressure (in confined aquifers), discharge flux, and water quality. Of all groundwater dependent ecosystems, aquifer ecosystems are entirely groundwater dependent, but details of their biota, ecosystem processes and water requirements are the least known.

This study applied the framework for determining environmental water requirements of aquifer ecosystems in a case study of the Peel Valley Alluvium, an alluvial aquifer connected to the regulated Peel River in the north-east Murray-Darling Basin, New South Wales, Australia. Eleven groundwater monitoring bores were sampled to determine whether structural indicators (abundance and taxonomic richness) of the groundwater invertebrate assemblage composition were correlated with aspects of the groundwater regime. Stygofauna (groundwater invertebrates) and physico-chemical variables were sampled quarterly in these bores from July 2006 to October 2007. Data loggers in 10 of the bores recorded groundwater level and temperature hourly for this period. Long-term stream gauge and groundwater level data were used to investigate the relationship between streamflow and groundwater regime, and to assess the degree of hydrological alteration in the river and alluvium after river regulation.

Before regulation, discharge in the Peel River was variable, with periods of low or no flow and periods of overbank flooding. Since dam construction, mean stream discharge has reduced, no-flow periods and flooding have been almost eliminated, and streamflow is less variable. These hydrologic changes are paralleled in the groundwater regime, with lower overall groundwater levels and reduced amplitude of water level fluctuations under regulated conditions. Comparison of stream stage and groundwater level data showed that a relationship exists between streamflow and groundwater regime, but the strength of this relationship varies in different parts of the alluvium. Analysis of hydrological and physico-chemical variables supported the prediction of hydrological connectivity between the Peel

River and the alluvium. Principal components analysis grouped the study bores by shared characteristics (amplitude of water level, specific conductivity) which can be interpreted as reflecting the degree of connectivity with surface water. The Peel Valley Alluvium is inhabited by a diverse stygofauna of at least 54 invertebrate taxa of which 33 are obligate groundwater inhabitants. Despite a broad association between faunal variables (abundance and morphotaxa richness) and specific conductivity, average temperature and dissolved oxygen, bores with the highest abundance and richness were not distinguished by these variables. Multivariate analysis found that different environmental variables correlated with faunal data for each sampling period and at each site. The varying associations between hydrological and water quality variables and faunal assemblage structure suggest that these variables are not the primary regulators of the biological pattern.

River regulation and groundwater extraction has induced a flow gradient from the river to the alluvium, creating conditions in the alluvium favourable to surface water fauna. The ability of stygofauna from the Peel Valley Alluvium to respond to the stressors of desiccation and water level drawdown was tested experimentally. Surface water copepods demonstrated an ability to survive in drying sediments for up to 48 h, and to respond to falling water levels by vertical movement. In contrast, amphipods did not respond to falling water levels with increased vertical movement. These results may explain the high abundance and widespread distribution of surface water copepods in the Peel Valley Alluvium. A predominance of surface water taxa in alluvial aquifers may be a common consequence of regulation of connected rivers.

A revised framework for determining environmental water requirements in alluvial aquifers is proposed which takes account of the organising principle of connectivity in delivering a compound disturbance regime, and recognizes the significance of scale and of cross-scale linkages between components of the disturbance regime. Given the current limits of distributional and taxonomic knowledge, the structural indicators of faunal assemblage composition appear inadequate to identify environmental water requirements for alluvial aquifers. The conjunctive use of functional indicators of ecosystem processes is recommended. Field-testing and further development of the framework will contribute to sustainable groundwater management, but realization of this goal relies on the collaboration of researchers, policy makers and knowledge brokers.

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ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ANZECC	Australia and New Zealand Environment and Conservation Council
CV	Coefficient of variation
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EWR	Environmental water requirements
EWP	Environmental water provisions
GDE	Groundwater dependent ecosystem
GWR	Groundwater regime
HCC	Hyporheic corridor concept
IHA	Index of hydrologic alteration
LGA	Local government area
mbgl	metres below ground level
MDS	Multi-dimensional scaling
MSS	Milieu souterrain superficial
NOx	Nitrite-and nitrate-nitrogen
NSW	New South Wales
NWC	National Water Commission
NWI	National Water Initiative
ORP	Oxidative-reductive potential
PCA	Principal components analysis
SWL	Standing water level
SRP	Soluble reactive phosphorus