

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.

Table of Contents

Certification	ii
Acknowledgements	iii
Abstract	iv
List of Figures	ix
List of Tables	xi
List of Abbreviations	xii
1 General introduction	1
1.1 Introduction.....	1
1.2 Policy context.....	1
1.3 Environmental flow methods in surface waters.....	7
1.4 Application of surface water environmental flow methods to groundwater.....	9
1.5 The ecological roles of disturbance and connectivity.....	10
1.6 The disturbance regime in river-alluvium ecosystems.....	12
1.7 Aim and hypotheses.....	14
1.8 Thesis structure.....	14
2 Hydrological patterns in the Peel River and its alluvium	17
2.1 Introduction.....	17
2.1.1 The role of flow regime in lotic ecology.....	17
2.1.2 Effects of the surface flow regime in connected alluvium.....	19
2.1.3 Aims and hypotheses.....	23
2.2 Study area.....	24
2.2.1 Physiography.....	24
2.2.2 Geology.....	25
2.2.3 Land use.....	28
2.2.4 Climate.....	28
2.2.5 Hydrological variability in the Peel River.....	29
2.2.6 The Peel Valley Alluvium.....	30
2.2.7 The natural resource management context.....	31
2.2.8 Existing environmental flow provisions in the Peel Valley.....	32
2.2.9 Study sites.....	32
2.3 Methods.....	34
2.3.1 Hydrological data and methods.....	34
2.3.2 Groundwater level data and methods.....	35
2.4 Results.....	37
2.4.1 The flow regime in the Peel River pre- and post-dam construction.....	37
2.4.2 The groundwater regime in the Peel Valley Alluvium pre- and post-dam construction.....	40
2.5 Discussion.....	50
2.5.1 The altered flow regime of the Peel River after regulation.....	50
2.5.2 Ecological impacts of disturbance to the flow regime.....	50
2.5.3 Surface water-groundwater connectivity in the Peel River-alluvium system.....	51
2.5.4 Ecological impacts of disturbance to the GWR.....	53
2.5.5 Knowledge gaps and further research needs.....	54
2.6 Conclusion.....	55
3 Spatial and temporal patterns in environmental variables in the Peel Valley Alluvium	56
3.1 Introduction.....	56
3.1.1 Recharge as a source of nutrients in alluvial ecosystems.....	56
3.1.2 Bacterial function in alluvial ecosystems.....	57

3.1.3	The role of ecotones: the hyporheic zone and the zone of intermittent saturation	58
3.1.4	Determinants of subsurface water flow: hydrological connectivity and hydraulic conductivity	59
3.1.5	The impacts of disturbance to the groundwater regime on biogeochemical processes	60
3.1.6	Aims and hypotheses	61
3.2	Methods	61
3.2.1	Field sampling	61
3.2.2	Laboratory analysis	62
3.2.3	Data analysis	62
3.3	Results	63
3.3.1	Water quality measures	63
3.3.2	Principal components analysis of environmental data	64
3.4	Discussion	75
3.4.1	Patterns of nutrient concentrations in the Peel Valley Alluvium	75
3.4.2	Environmental measures as indicators of hydrological connectivity	77
3.4.3	Implications of disturbance to the groundwater regime	80
3.4.4	Knowledge gaps and further research needs	81
3.5	Conclusion	82
4	Groundwater faunal responses to hydrological disturbance	83
4.1	Introduction	83
4.1.1	Adaptations of stygobitic fauna to the aquifer environment	84
4.2	Methods	86
4.2.1	Collection of fauna and sediments	86
4.2.2	Desiccation experiments	87
4.2.3	Faunal responses to water level drawdown	89
4.2.4	Statistical analysis	90
4.3	Results	91
4.3.1	Desiccation experiments	91
4.3.2	Faunal responses to water level drawdown	93
4.4	Discussion	95
4.4.1	Responses to water level drawdown and water level fluctuations	95
4.4.2	Hydrological conditions favourable to stygophilic taxa	96
4.4.3	Knowledge needs and future research directions	98
4.5	Conclusion	99
5	Associations between environmental variables and stygofaunal distribution in the Peel Valley Alluvium	100
5.1	Introduction	100
5.1.1	Associations between environmental variables and invertebrate assemblage composition in the hyporheic zone and aquifers	100
5.1.2	Flow regime as the “master variable”	103
5.1.3	The effects of flow regulation on aquatic macroinvertebrate assemblage composition	104
5.1.4	Frameworks for describing responses to changes in environmental variables	105
5.1.5	Aims and hypotheses	106
5.2	Methods	107
5.2.1	Field sampling	107
5.2.2	Laboratory processing of faunal samples	108
5.2.3	Data analysis	109
5.3	Results	112
5.3.1	Fauna	112

5.4 Discussion.....	127
5.4.1 Spatial and temporal trends in stygofaunal assemblage composition	127
5.4.2 Introduced species.....	127
5.4.3 Spatial dynamics of metapopulations.....	128
5.4.4 Spatial distribution of stygobites, stygoxenes and stygophiles.....	129
5.4.5 Associations between environmental variables and stygofaunal assemblage characteristics	130
5.4.6 Is species-level taxonomic resolution necessary?.....	133
5.4.7 Effects of river regulation on the stygofaunal assemblage	134
5.5 Conclusion	137
6 Synthesis	138
6.1 Introduction	138
6.2 Environmental disturbance in the Peel Valley Alluvium.....	139
6.3 A framework for investigating EWRs for alluvial aquifers	141
6.4 Improving the integration of science into policy	145
References	149
Appendix A	180
Appendix B	186

List of Figures

Figure 1.1 Conceptual model of the process of determining environmental water requirements for a river-alluvium system.	11
Figure 1.2 Thesis structure and the principal themes in each chapter.	16
Figure 2.1 Location of study area and study bores.	26
Figure 2.2 Outline of study area showing groundwater monitoring bores (▲) and stream gauges (●) referred to in the text.	27
Figure 2.3 Mean monthly rainfall (bars) and mean monthly maximum and minimum air temperatures at Tamworth Airport (1992 – 2007).	29
Figure 2.4 Mean monthly discharge ($\text{m}^3 \text{sec}^{-1}$) at stream gauges 419015 (a) and 419009 (b) in the Peel River for periods before and after construction of Chaffey Dam.	38
Figure 2.5 Groundwater levels in metres below ground level (mbgl) in bores 30167 (a) and 30136 (b) in the Peel Valley Alluvium.	41
Figure 2.6 A rain event in August 2007 (a) is reflected in a rise in river stage at three gauges (b,d,g) and in groundwater levels in five bores (c,e,f,h,i) in the Peel Valley Alluvium.	44
Figure 2.7 River stage at gauge 419045 (a) and groundwater levels in the adjacent bores (b,c,d,e) for the same time period as for Fig. 2.6.	46
Figure 2.8 River stage at gauge 419045 (a) and groundwater levels in the adjacent bores (b,c,d,e) for the duration of the study period.	47
Figure 2.9 River stage at three gauges (a,c,f) and groundwater levels in adjacent bores (b,d,e,g,h) for the duration of the study period.	48
Figure 3.1 pH (a) and temperature (b) in the study bores and at one site in the Peel River on six sampling occasions.	66
Figure 3.2 Specific conductivity (a) and dissolved oxygen (b) in the study bores and at one site in the Peel River on six sampling occasions.	67
Figure 3.3 Oxidative-reductive potential (a) and dissolved organic carbon (b) in the study bores and at one site in the Peel River on six sampling occasions.	68
Figure 3.4 NO _x (a) and SRP (b) in the study bores and at one site in the Peel River on six sampling occasions.	69
Figure 3.5 Measurements of pH (a) and specific conductivity (b) in the study bores in the Peel Valley Alluvium and one site in the Peel River.	71
Figure 3.6 Measurements of NO _x (a) and SRP (b) in the study bores in the Peel Valley Alluvium and one site in the Peel River.	72
Figure 3.7 Daily specific conductivity spot values in the Peel River at Tamworth (a) and rainfall over the study period at Tamworth Airport (b).	73
Figure 3.8 Principal components analysis of environmental variables in bores in the Peel Valley Alluvium with vectors showing the contributions of variables to the axes.	74
Figure 4.1 Dishes of sediment used in the desiccation experiments.	88
Figure 4.2 Modified syringe used in the water level drawdown experiments.	89
Figure 4.3a Copepod survival in the desiccation experiment.	92
Figure 4.3b Amphipod survival in the desiccation experiment.	92
Figure 4.4 Saturation ratio at the end of the desiccation experiment plotted against fitted probability of survival for dishes containing five copepods.	93
Figure 4.5 Number of copepods (a) and amphipods (b) recovered from the four depth fractions in treatment (closed bars) and control (hatched bars) microcosms.	94

Figure 4.6 Conceptual model of the effect of anthropogenic disturbance on stygofaunal assemblage composition in the Peel Valley Alluvium.....	98
Figure 5.1 Stygofaunal abundance (a), morphotaxa richness (b), morphospecies richness (c) and stygobitic richness (d) in the study bores.	116
Figure 5.2 Schematic diagrams of a) abundance and b) morphotaxa richness in the study bores.	118
Figure 5.3 Schematic diagrams of a) morphospecies richness and b) stygobitic richness in the study bores.	119
Figure 5.4 MDS plots of faunal data at a) morphotaxa level and b) morphospecies level taxonomic resolution.	120
Figure 5.5 Scatter plots of hydrological and water quality variables and log-transformed abundance.	121
Figure 5.6 Scatter plots of hydrological and water quality variables and morphotaxa richness.	122
Figure 5.7 Scatter plots of hydrological and water quality variables and morphospecies richness.	123
Figure 5.8 Scatter plots of hydrological and water quality variables and stygobitic richness.	124
Figure 5.9 Relationship between morphospecies richness and stygobitic richness (a) and morphotaxa richness and morphospecies richness (b) in the study bores.	126
Figure 6.1 Static conceptual model of the ecological effects of water resource development in the Peel Valley Alluvium.	140
Figure 6.2 Revised conceptual model of the process of determining environmental water requirements for a river-alluvium system.	148

List of Tables

Table 1.1 Environmental outcomes and five year water management targets relevant to groundwater in the NSW State Water Management Outcomes Plan.	6
Table 1.2 River Flow Objectives (RFOs) identified in the NSW <i>Water Management Act 2000</i>	7
Table 2.2 Location and description of bores sampled during the study.	33
Table 2.3 Proximity of the study bores to surface water and stream gauges.	34
Table 2.4 Overview of NSW Department of Water and Energy records of streamflow and groundwater level for the study area.	36
Table 2.5 Index of Hydrologic Alteration results for discharge data ($\text{m}^3 \text{sec}^{-1}$) from stream gauges 419015 and 419009 in the Peel River before and after dam completion in 1979. .	39
Table 2.6 Index of Hydrologic Alteration results for groundwater data (mbgl) from bores 30167 and 30136 in the Peel Valley Alluvium before and dam completion in 1979.	42
Table 2.7 Relationship between changes in stage in the Peel River and groundwater level in the study bores.	45
Table 2.8 Mean water levels (WL), coefficients of variation in groundwater level (CV), and maximum amplitude of water level (Amp) in the study bores.	49
Table 3.1 Measured environmental variables in the study bores in the Peel Valley Alluvium and one site in the Peel River.	70
Table 3.2 Coefficients of the eigenvectors in the linear combinations of variables making up the principal components, and eigenvalues and variance accounted for by each axis. .	74
Table 4.1 Treatments used in the desiccation experiment with copepods.	88
Table 5.1 Variables used in statistical analysis	111
Table 5.2 List of fauna collected from the study bores in the Peel Valley Alluvium, and number of individuals of each taxon.	113
Table 5.3 Morphotaxa abundance from six sampling occasions.	115
Table 5.4 Results table for repeated measures ANOVA for log-transformed abundances and morphotaxa richness, morphospecies richness and stygobitic richness.	117
Table 5.5 Highest correlations from the BIOENV procedure matching environmental variables with morphospecies data.	125
Table 6.1 Information required for formulating environmental water requirements for alluvial aquifer ecosystems.	144
Table 6.2 Suggested framework for assessing environmental water requirements for alluvial aquifer ecosystems.	147

List of Abbreviations

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
NO _x	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