EXPLORING THE USE OF WATER MARKETS FOR IMPROVED ENVIRONMENTAL OUTCOMES

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IV. Abbreviations, Units and Terminology

List of Abbreviations

ABARE-BRS	Australian Bureau of Agricultural and Resource Economics and the Bureau of Rural Sciences
ABARES	Australian Bureau of Agricultural Economics and Science
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission
ACT	Australian Capital Territory
BOM	Bureau of Meteorology
CBWTP	Columbia Basin Water Transaction Program
CER	Clean Energy Regulator
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CGE	Computable general equilibrium model
CICES	Common International Classification of Ecosystem Services
CLLMM	Coorong, Lower Lakes and Murray Mouth
COAG	Council of Australian Governments
CRDWT	Colorado River Delta Water Trust
CSIRO	Commonwealth Scientific Research and Industrial Research Organisation
DEWHA	Department of Environment, Water, Heritage and the Arts
DEWNR	Department of Environment, Water and Natural Resources
DoAWR	Department of Agriculture and Water Resources
DoE	Department of the Environment
DoEE	Department of the Environment and Energy
EPA	Environmental Protection Agency
ES	Ecosystem services
EU ETS	European Union Emissions Trading Scheme
EWH	Environmental water holder
EWTF	Environmental water trading framework
GVAP	Gross value of agricultural product
GVIAP	Gross value of irrigated agricultural product
GWP	Global Water Partnership
HEM	Hydro-economic model
HSI	Habitat suitability index
IPCC	Inter-governmental Panel on Climate Change
IWG SC-CO_2	International Working Group on the Social Cost of Carbon
IWRM	Integrated water resource management
MAE	Millennium Ecosystem Assessment
MDBA	Murray-Darling Basin Authority
MDB	Murray-Darling Basin
MDB BWF	Murray-Darling Basin Balanced Water Fund
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Ministerial Council
NGO	Non-government organisation
nMDB	Northern Murray-Darling Basin
NPWS	National Plan for Water Security
NSW	New South Wales
NWC	National Water Commission
NWI	National Water Initiative
OECD	Organisation for Economic Co-operation and Development

OEH	Office of Environment and Heritage
OWT	Oregon Water Trust
PC	Productivity Commission
PE	Partial equilibrium
PO	Pareto optimality
PPO	Potential Pareto optimality
QLE	Qualified Local Entity
RTB	Restoring the Balance
RtB	Restoring the Balance
SA	South Australia
SC-CO_2	The social cost of carbon
SDL	Sustainable Diversion Limit
SEACI	South Eastern Australian Climate Initiative
sMDB	Southern Murray-Darling Basin
SRA	Sustainable Rivers Audit
SRWUIP	Sustainable Rural Water Use and Infrastructure Program
TC	Transaction cost
TEEB	The Economics of Ecosystems and Biodiversity
TLM	The Living Murray
TLM	The Living Murray
USDA	United States Department of Agriculture
USED	Upper South East Drainage
US-EPA	United States Environmental Protection Agency
US-FWS	United States Fish and Wildlife Service
WFF	Water for the Future
WGCS	Wentworth Group of Concerned Scientists
WTO	World Trade Organisation
WUA	Water user association

List of Units Used

$AU	Australian dollar[1]	(~0.75 $US)
AF	Acre foot	(1.23 x 10^6 litres)
EC	Electro conductivity	(1 µS/cm)
GL	Giga litre	(1x10^9 litres)
Ha	Hectare	(1 x 10^{-2} km^2)
ML	Mega litre	(1 x 10^6 litres)
tC	Tonnes of carbon	(1 x 1000kgC)
tCO_{2e}	Tonnes of carbon dioxide equivalent	(1 x 1000kgCO_{2e})

[1] Unless otherwise indicated all dollar values are in Australian dollars.

Useful Terminology

2800GL *Basin Plan* hydrological scenario	June 2009 hydrological conditions adjusted for an additional 2800GL environmental water in the MDB.
Allocation water trade (see also: water allocation)	The temporary (e.g. annual) sale of water ascribed to a water entitlement.
Appropriation	The abstraction and beneficial use of water from a water resource system. The appropriation date (see: *prior appropriation*) is set from the first date of appropriation of the water right.
Bankfull discharge	The flow volume which connects the river channel to the floodplain. Flow greater than bankfull discharge results in floodplain inundation.
Baseline hydrological scenario	June 2009 hydrological and development conditions in the MDB.
Catchment water balance	A mathematical representation of all catchment inflows, losses, storages and outflows.
Commonwealth Environmental Water Holder (CEWH)	A federal agency established by the *Water Act* (*Cwth* 2007) responsible for the management of environmental water acquired by the Australian federal government. The water rights managed by CEWH is 'held' environmental water (see: *environmental water*)
Consumptive water-use	The abstraction of water which results in the permanent removal or diminishment of water from its source. The volume of water 'taken up' is the consumptive water-use volume (e.g. domestic water-use).
Council of Australian Governments (COAG)	A group consisting of the Prime Minister of Australia, the First Ministers of Australian states and territories, and the President of the Australian Local Government Association. COAG is charged with managing matters of national significance that need to be co-ordinated across states and territories (e.g. the Basin Plan).
Decision horizon (also: *planning horizon*)	The number of years considered in a forecast of future events and relevant information when making a decision (see also: *rolling horizon*).
Demand-based water management	Water management strategies that seek to change the consumptive demand patterns for freshwater through the use of voluntary measures (e.g. education programs), rules and regulation (e.g. water restrictions), and economic instruments (e.g. water markets and water pricing).
Economic water scarcity	Water scarcity that occurs when a population does not have the necessary monetary or human capital to access volumes of water adequate to meet consumptive demand.
Ecosystem services	The services provided by the natural environment, which support the survival and well-being of human populations.
Entitlement water trade	The permanent sale of a water entitlement or water right (see also: *water entitlement*).
Environmental asset	Naturally occurring ecosystems or biomes that provides environmental services or functions. (Note that this definition is adopted from the OECD (2005) *Handbook of National Accounting* and differs from the ABS definition, which requires an asset to have an identifiable owner who derives economic benefit from holding or using the environmental asset (ABS, 2010a).
Environmental steward	An individual or entity whom engages in the sustainable use and protection of the natural environment and its functions.
Environmental water	Water designated to maintain, protect or restore ecological character of freshwater ecosystems. In the MDB, environmental water is either *rules-based* (volume prescribed by water-sharing plans) or *held* (acquired by an environmental water holder from consumptive water users).

Environmental water holder	An entity, government or otherwise, with a mandate to manage acquired (or *'held'*) water rights/entitlement for environmental benefit
Environmental water product (also: *environmental water transfer tool*)	A water right/entitlement, or aspect thereof, that is acquired on the water market and used for environmental use (see also: *water product*).
Environmental water transaction (also: environmental water transfer)	A market style transaction in which an environmental water product is transferred from consumptive use to environmental use.
Federation drought	A hydrological drought affecting much of Australia from 1897 to 1903.
Flow-dependent ecosystem	Natural ecosystems dependent upon the provision of freshwater flows to support and maintain ecological function.
Groundwater	Fresh water stored below the surface of the Earth in the soil and in acquirers.
High security water entitlement	A water entitlement which reliably yields full allocation volumes in approximately 90-95 years out of 100 in the MDB, with little variation between years except during extreme drought conditions.
Hydro-economic model	A mathematical model integrating hydrological and economic principles.
Hydrological catchment (also: *drainage basin*)	The geographic extent for which all surface water runoff converges to a single low-elevation point. In the MDB, a 'catchment' often refers to one of the 22 sub-catchments of the wider MDB.
Hydrological indicator site	The 18 environmental assets in the MDB for which environmental watering requirements were quantified for the Basin Plan.
Long-term average annual yield	The expected long-term average yield from a water entitlement over a 100 year period.
Low/general security water entitlement	A water entitlement which yields a variable allocation depending on water availability. General security water entitlements provide a LTAAY of 42-81% and low security yields between 24-35% in the MDB.
Millennium drought	A prolonged hydrological drought affecting the majority of south-eastern Australia. Prolonged periods of dry conditions were experienced from late 1996 to mid-2010 (BOMb, 2015), and the height of the Millennium Drought was experienced from 2001 to 2009.
Non-consumptive water-use	The use of water which does not result in the permanent removal or diminishment of water from its source (e.g. in-situ environmental watering)
Non-government organisation	An organisation, typically non-profit, which is independent from state, federal or international governments.
Normative framework	A framework or method to help analyse normative trade-offs.
Over-allocated (also: *over-appropriated*)	The state of a water resource system when the volume of water rights/entitlements held by consumptive and non-consumptive water users exceeds the long-term average volume of water available for use.
Physical water scarcity	Water scarcity that occurs when water resource development is approaching or has exceeded sustainable diversion limits, such that there is not enough water to meet all demands.
Prior appropriation doctrine	The dominant water law applied to the western United States, characterised by "*first in time, first in right*" abstraction priorities and beneficial use clauses.
Ramsar Convention	An international treaty identifying internationally important wetlands developed in Ramsar, Iran.
Regulated river	A river subject to major water resource development such that downstream flows are regulated by major upstream water storage infrastructure.

Resilience	The ability for a system to resist or recover from perturbation to its original long-term state.
River Red Gum (also: *Eucalyptus camaldulensis*)	A large, long-lived Eucalyptus tree species indigenous to Australia. It is commonly found along watercourses and is reliant upon regular flooding in ecologically desirable volumes and frequencies.
Rolling horizon	In a rolling horizon decision-making approach, the decision maker makes the most immediate decision (e.g. decisions in the first period) based on knowledge of conditions in the present period and an uncertain (e.g. probabilistic or stochastic) forecast of the remaining years in the decision horizon. In the next period, the second period decisions become the most immediate and the decision horizon is pushed out further into the future, and is thus 'rolled over'.
Supply-based water management	Water management strategies that seek to increase and more effectively manage the supply of freshwater for consumptive use, including measures such as water treatment plants (e.g. desalinisation), water transport and delivery systems (e.g. pipes, channels), infrastructure construction and upgrades (e.g. dams and weirs).
Surface-water	Fresh water stored in the surface of the Earth in rivers, streams, lakes and reservoirs.
Sustainable diversion limit (SDL)	An upper level of water-use that limits the amount of water that can be used for consumptive purposes in the MDB.
The Commonwealth	The Federal Commonwealth Government of Australia
The Murray-Darling Basin Plan (also: *the Basin Plan*)	A co-ordinated approach between state, territory and federal governments to manage water resources in the MDB. The *Basin Plan* was passed into law in 2012 and the initial sustainable diversion limits will come into full effect in 2019.
The Paris Agreement	A global agreement on climate change mitigation actions developed during the 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change held in Paris, France. Australia ratified the Paris Agreement in 2016 and it entered into force in November of that year.
Water allocation	The volume of water credited to a water entitlement able to be used in a season, dependent on the total water available in the system and the security of the water entitlement.
Water entitlement (also: *water access entitlement*)	The right to an ongoing share of a total amount of water available in a water resource system. Water entitlements yield annual water allocations. Internationally and commonly referred to as a *water right.*
Water product	A water right, or aspect thereof, that is sold on the water market. Water products are characterised by the type (e.g. groundwater, surface-water), the duration of the water right exchange (e.g. annual, permanent, 5 year lease), and any other contractual characteristics (e.g. dry-year trigger arrangement). (See also: *environmental water product*).
Water user association (also: *water user board*)	A group of water users, such as irrigators, who combine financial, technical and social resources to manage and maintain a water supply system.
Water year (also: *water accounting year*)	The 12 months period commencing each year on the 1st of July.
Without development hydrological scenario	Modelled hydrological conditions without any water resource development and major water abstraction in the MDB.

V. Abstract

Water resource development has historically proceeded with little consideration for the environment. In the Murray-Darling Basin (MDB) Australia, water resource development has resulted in considerable ecological degradation and a diminishment of flow-dependent ecosystem services (ES). In response, MDB water policy has undergone considerable reform in the past decade, culminating in a commitment to reallocate water from consumptive use back to the environment. This thesis examines potential further use of water markets, and issues associated with this, to provide greater and more efficient environmental flows.

The main question investigated in this thesis was the potential for an environmental water holder (EWH) to use the water allocation market to reallocate water to the environment for improved ecological condition and ES generation. To answer this question, an interdisciplinary mixed-methods approach was employed involving: a) the development of a hydro-economic model that simulates the annual trade decisions of a forward-looking EWH in a MDB sub-catchment; b) 49 qualitative face-to-face interviews across the US and Australia with stakeholders from industry, non-profit and government agencies regarding the role of non-government environmental water holders (NGO EWHs); and c) quantitative survey analysis of 1,000 southern MDB irrigator preferences in 2015-2016 for the sale of environmental water.

Key findings of this thesis show that trading water allocations for the environment can have positive ES benefits by improving floodplain inundation. Under particular hydrological and fiscal conditions, the increase in floodplain carbon storage may be of sufficient market value to offset the cost of environmental water allocation purchases. This indicates a potential carbon-water trading strategy which may provide a novel revenue stream for self-financing EWHs. It was shown that NGO EWHs play a unique role in environmental water reallocation through the provision of flexible and multi-functional water trade arrangements. Results also highlight the importance of social capital in facilitating successful environmental water trades. Lastly, results demonstrate that southern MDB irrigators show a clear preference for the local management of water resources, and in particular NSW and Victorian irrigators rank the federal government among their least preferred buyers of water entitlements. Southern MDB irrigators also demonstrate a clear preference for the use of water allocation trade for the environment.

Key recommendations based on these results include: a) the further judicious expansion of market-based reallocation policies, particularly water allocation trade, in place of continued infrastructure-based reallocation; b) the use of carbon credit generation and sale to cost-effectively finance annual environmental water reallocation; and c) the need to encourage an increased partnership of federal agencies with local and NGO EWHs, in order to increase irrigator participation and sustain local values in environmental water management.

VI. Thesis Declaration Statement

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree. I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. I acknowledge that copyright of published works contained within this thesis resides with the copyright holder(s) of those works. I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

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Claire Settre

September, 2017

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VIII. Publications and Presentations from this Thesis

Academic Journal Articles (peer-reviewed)

Settre, C. & Wheeler, S. (2017) A century of interventions in a Ramsar wetland – the case of the Coorong, Lower Lakes and Murray Mouth, *Australasian Journal of Environmental Management*, 24(2), pp. 1-21.

Settre, C., Connor, J. & Wheeler, S. (2017) Reviewing the treatment of uncertainty in hydro-economic modelling in the Murray-Darling Basin. *Water Economics and Policy*, 3(3), pp.35, DOI: 10.1142/S238264X16500429

Book Chapters (peer-reviewed)

Settre, C. & Wheeler, S. (2016) Environmental water governance in Australia: the movement from regulation and engineering to economic-based instruments. In: V. Ramiah and G. Gregoriou (eds), *Handbook of Environmental and Sustainable Finance*, New York: Elsevier, pp. 67-91.

Settre, C. & Wheeler, S. (2017) Rebalancing the system: acquiring water and trade. In: A. Horn, A. Webb, M. Stewardson, B. Richter, B., M. Acreman (eds), *Water for the Environment: From Policy and Science to Implementation and Management.* London: Elsevier, pp. 399-419.

Current Working Papers

Settre, C., Connor, J. & Wheeler, S. (2017) Can the generation and sale of carbon credits in natively vegetated floodplains offset the costs of annual environmental water purchases?

Settre, C., Connor, J. & Wheeler, S. (2017) Strategic water and carbon market opportunities for a self-financed environment water holder to improve floodplain forest carbon storage.

Settre, C. (2017) Localism, community engagement and 40 Cups of coffee: the role of non-government organisations as stewards of environmental water in the western USA and potential insights for the Murray-Darling Basin, Australia.

Settre, C., Connor, J. & Wheeler, S. (2017) Estimating the economic value of environmental water with ecosystem service supply modelling.

Conference Papers and Seminars

Settre, C. (2017) Water without borders: the who, what and why of international water research. *The University of California, Riverside, Extension Centre Research Series,* 17th February 2017, Riverside, USA.

Settre, C. (2017) Realising floodplain benefits of environmental water reallocation with improved ecosystem services accounting. *The University of California, Riverside, School of Public Policy Seminar Series.* 24th October 2017, Riverside, USA.

Settre, C., Connor, J. & Wheeler, S. (2016) Ecosystem service dynamics in the Murray-Darling Basin: managing water for improved carbon stocks. *NCCARF and CSIRO Climate Adaptation Conference,* 5th – 7th of July 2016, Adelaide, Australia.

Settre, C., Connor, J., Wheeler, S. (2016) Ecosystem service dynamics in the Murrumbidgee catchment, Australia. *Natural Resource Management Science Conference*, 13th -15th April 2016, Adelaide, Australia.

Settre, C., Connor, J., Wheeler, S. (2016) Improving ecosystem services through trade in the Murrumbidgee catchment, Australia, *60th National Australian and Agricultural Resource Economics Society Conference*, 2nd-5th February, 2016. Canberra, Australia.

Settre, C. (2015) Informing environmental water management using ecosystem service values in the Murrumbidgee catchment, Australia. *The University of Adelaide Centre of Global Food Studies Seminar Series,* Adelaide, Australia.

Settre, C. (2015) A century of water resource management in a Ramsar wetland – a case study of the Coorong, Lower Lakes and Murray Mouth, Australia, *59th National Australian Agricultural Resource Economics Society Conference*, 10th-13th February 2015, Rotorua, New Zealand.

Settre, C. (2014) Australia's environmental water governance: from state to market? *Global Conference on Managing in Recovering Markets,* 8th-9th November 2014, Adelaide, Australia.

IX. Additional Publications during Candidature

Academic Journal Articles (peer-reviewed)

Loch, A., Wheeler, S., **Settre, C**. (*forthcoming*) Private transaction costs of water trade in the Murray-Darling Basin. *Ecological Economics.*

Book Chapters (peer-reviewed)

Palomo-Hierro, S., **Settre, C.,** Wheeler, S., Loch, A. (2016) The Australian and Californian water market experience: an example to follow? In: J. Gomez-Limon and J. Calatrava (eds.), *Water Markets in Spain: Present and Future*, Cajamar Caja Rural, Spain, pp. 315-345.