

Global Issues in Water Policy 24

Jean-Daniel Rinaudo
Cameron Holley
Steve Barnett
Marielle Montginoul *Editors*

Sustainable Groundwater Management

A Comparative Analysis of French and
Australian Policies and Implications
to Other Countries

 Springer

Global Issues in Water Policy

Volume 24

Editor-in-chief

Ariel Dinar, Department of Environmental Sciences, University of California,
Riverside, California, USA

Series Editors

José Albiac-Murillo, Zaragoza, Spain

Stefano Farolfi, CIRAD UMR G-EAU, Montpellier, France

Rathinasamy Maria Saleth, Chennai, India

Guillermo Donoso, Department of Agricultural Economics, Pontificia Universidad
Católica de Chile, Macul, Chile

More information about this series at <http://www.springer.com/series/8877>

Jean-Daniel Rinaudo • Cameron Holley
Steve Barnett • Marielle Montginoul
Editors

Sustainable Groundwater Management

A Comparative Analysis of French
and Australian Policies and Implications
to Other Countries

 Springer

Editors

Jean-Daniel Rinaudo
BRGM
Montpellier University
Montpellier, France

Cameron Holley
Faculty of Law
University of New South Wales Sydney
Sydney, NSW, Australia

Steve Barnett
Adelaide, SA, Australia

Marielle Montginoul
INRAE – UMR G-Eau, Montpellier
University, Montpellier, France

ISSN 2211-0631

ISSN 2211-0658 (electronic)

Global Issues in Water Policy

ISBN 978-3-030-32765-1

ISBN 978-3-030-32766-8 (eBook)

<https://doi.org/10.1007/978-3-030-32766-8>

© Springer Nature Switzerland AG 2020

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The idea for this book was born in November 2015 during a professional visit to Australia by Jean-Daniel Rinaudo, who had the opportunity to meet with Cameron Holley and Steve Barnett, as well as many of their colleagues in Adelaide, Melbourne, Canberra and Sydney to discuss many aspects of groundwater management. During the enthusiastic and productive exchanges that took place during this visit, it soon became clear to us that management policies and planning tools in both France and Australia were based on similar foundations and that continuing to share knowledge and experience would be mutually beneficial.

A year later after the IAH International Congress in Montpellier (France) in September 2016, we met again for a two-day workshop that brought together 30 French and 13 Australian experts, all directly involved in the management and planning of groundwater resources. For many participants, this workshop offered them the opportunity to share the results of several decades of personal experience for the first time and to engage with their peers from the other side of the world. One of the highlights of this meeting was the moment when each delegation reported their views of each other's management model in a game called 'report of bewilderment'. The main finding was that, reassuringly, French and Australian water managers employ similar approaches to solve similar problems using similar technology. But it was also the realisation of the existence of fundamental philosophical differences, of a 'clash of civilizations'. This was mostly apparent on the subject of ownership of water use rights where the French rejected the idea of water markets, while the Australians expressed a polite perplexity regarding the collective management of water allocation to existing water users.

At the end of the workshop, many participants agreed to contribute to an edited book so that the management approaches and techniques discussed therein may inform and benefit their peers, groundwater managers from other countries and future generations. A collective work project was thus submitted to Ariel Dinar, who strongly encouraged us to pursue the project. The group was extended to include several academic and professional experts from Australia, France and other nations in order to meet the requirements of an academic publication and to extend the coverage of the book. Although the editorial efforts were a collective endeavor, a

significant amount of the work was shouldered by Rinaudo, whose leadership and diligence drove this collection. *Merci de nous avoir menés, Jean-Daniel*. Eighteen months later, the collection was completed. Our hope is that the comparative insights from the completed book will assist groundwater managers and scholars across the globe and, by doing so, help contribute to the efforts of the UN High Level Panel on Water's *Agenda for Water Action (2018)*, which calls for efforts 'catalyzing change, building partnerships & international cooperation at the global level'.

This journey has benefited from many supports that we wish to thank here. The initial work visit carried out in 2015 was financed by the National Research Agency (ANR) and Brgm as part of the Arena Groundwater project. The French Embassy in Australia also supported the short mobility visit of Cameron Holley to Montpellier in 2016 (Scientific Mobilisation Grant 2016), and Holley's work on the book benefited from an Australian Research Council Discovery Early Career Researcher Awards (DE140101216) and an Australian Research Council Discovery Grant (DP170100281). The Rhône Méditerranée Corse Water Agency subsequently funded the organisation of the workshop in Montpellier in September 2016. This could not have happened without the tremendous motivation of the Australian experts who convinced their institutions of the value of this exchange or who personally financed their travel to France. Brgm actively financed the translation or the English editing of most French chapters. Our translators, in particular Isis Olivier, must also be thanked for the quality of their work, as well as Emilie Lenoir and Marie-Adélaïde Ethève for editing the manuscript. Finally, this book was only made possible by the dedication and hard work of the chapter authors, and we are extremely grateful to all of them for their willingness to collaborate on this project.

Montpellier, France
 Sydney, Australia
 Adelaide, Australia
 Montpellier, France

Jean-Daniel Rinaudo
 Cameron Holley
 Steve Barnett
 Marielle Montginoul

About the Book

The book comprises 27 chapters, covering four main topical areas. Chapters 1 to 10 provides background information on the French and Australian groundwater resources and policy context at federal and national levels, as well as at river basin level, where groundwater policy implementation and long-term planning actually takes place. Contributors describe how groundwater policies have progressively structured over the last 25 years, using primary information accumulated during their career, with the support of academic authors providing conceptual frameworks for policy analysis. The confrontation of the Australian and French approaches reveals fundamental political and philosophical values in relation to the property of water and to the role that users' communities should play in allocation.

Chapters 11 to 16 deal with conceptual approaches and operational tools used to assess sustainable abstraction limits. Contributions highlight the differences between conceptual approaches prevailing in the two countries. While French policy makers assert that sustainable should be defined based on scientific evidence, their Australian counterpart acknowledge that such limits must be acceptable, thus negotiated between stakeholders. This part of the book also provides a good overview of the tools and models used to estimate extraction limits at different geographic and time scales, considering climate variability and uncertainties about future changes. Some chapters also look at this issue from a political economy perspective, highlighting that extraction limits result from a negotiation where scientific evidence only plays a limited role.

Chapters 17 to 24 focus on approaches implemented to reduce groundwater entitlements in over-exploited aquifers. A number of case studies illustrate the different policy approaches that can be used to restore long-term sustainability. Issues addressed in these chapters include that of financial compensation for cutbacks in entitlements (either through buy-back programmes or the development of substitution water resources), possible differentiated treatment of used and sleeping water rights, the unbundling of water entitlements, and allocations. Two chapters discuss compliance and enforcement problems, the intensity of which increases as water scarcity rises. The part ends with a discussion of the linkages between groundwater management and agricultural policies.

The last two chapters develop an international perspective of the issues addressed in the book through contributions from California and Chile. A concluding chapter draws lessons from French, Australian and international experiences, highlighting common features observed in the long pathways taken by various countries to shift from open access to sustainable groundwater abstraction regimes.

Contents

1	Sustainable Groundwater Management in France and Australia: Setting Extraction Limits, Allocating Rights and Reallocation	1
	Cameron Holley, Jean-Daniel Rinaudo, Steve Barnett, and Marielle Montginoul	
2	Groundwater in France: Resources, Use and Management Issues	17
	Jean-Christophe Maréchal and Josselin Rouillard	
3	Groundwater Policy in France: From Private to Collective Management	47
	Jean-Daniel Rinaudo	
4	Groundwater Management Planning at the River Basin District Level: Comparative Analysis of the Adour-Garonne and Loire-Bretagne River Basins	67
	Jean-Daniel Rinaudo, Pierre Marchet, and Pascal Billault	
5	Lessons from Twenty Years of Local Volumetric Groundwater Management: The Case of the Beauce Aquifer, Central France	93
	Frederic Verley	
6	Groundwater in Australia: Occurrence and Management Issues . . .	109
	Steve Barnett, Nikki Harrington, Peter Cook, and Craig T. Simmons	
7	The Evolution of Groundwater Management Policy in the States of Australia.	129
	Rebecca Nelson, Steve Barnett, and Ann Kollmorgen	

8	Developing a Coordinated Groundwater Management Plan for the Interstate Murray-Darling Basin	143
	Glen Walker, Steve Barnett, and Stuart Richardson	
9	Information Systems for Sustainable Management of Groundwater Extraction in France and Australia	163
	John Sharples, Elisabetta Carrara, Lindsay Preece, Laurence Chery, Benjamin Lopez, and Jean-Daniel Rinaudo	
10	The Challenge of Making Groundwater Visible: A Review of Communication Approaches and Tools in France	191
	Audrey Richard-Ferroudji and Gaïa Lassaube	
11	Conceptual Approaches, Methods and Models Used to Assess Abstraction Limits for Unconfined Aquifers in France	211
	Luc Arnaud	
12	Setting Sustainable Abstraction Limits in Confined Aquifers: Example from Deep Confined Aquifers in the Bordeaux Region, France	229
	Frédéric Lapuyade, Marc Saltel, and Bruno de Grissac	
13	A Tool to Determine Annual Ground-Water Allocations in the Tarn-et-Garonne Alluvial Aquifer (France)	253
	Pierre Le Cointe, Vorlette Nuttinck, and Jean-Daniel Rinaudo	
14	Conceptual Approaches, Methods and Models Used to Assess Extraction Limits in Australia: From Sustainable to Acceptable Yield	275
	Daniel Pierce and Peter Cook	
15	Case Study: An Integrated Approach to Determining Sustainable Abstraction Limits in Perth's North West Urban Growth Corridor	291
	Mal McGivern and Clive Hampton	
16	Using Resource Condition Limits to Define Groundwater Management Objectives in the Barossa Valley, South Australia	299
	Daniel Pierce, Roger Cranswick, and Megan Hancock Lane	
17	Reducing Entitlements When Groundwater Has Been Over-Allocated: Policy Issues and Options	315
	Stefanie Schulte and Gabriela Cuadrado Quesada	
18	Developing Substitution Resources as Compensation for Reduced Groundwater Entitlements: The Case of the Poitou Marshes (France)	333
	Olivier Douez, Jean Eudes du Peuty, Daniel Lepercq, and Marielle Montginoul	

19 New Approaches for Allocation Reductions and Groundwater Salinity Management in South Australia 355
 Steve Barnett and David Williamson

20 Reducing Groundwater Entitlements in the Lower Murrumbidgee Groundwater Management Area 365
 Ken Schuster, Amanda Kennedy, and Cameron Holley

21 Development of Groundwater Markets in Australia: Insights from Victoria in the Murray Darling Basin 385
 Julia De Luca and Darren Sinclair

22 Groundwater Regulation, Compliance and Enforcement: Insights on Regulators, Regulated Actors and Frameworks in New South Wales, Australia 411
 Cameron Holley, Tariro Mutongwizo, Susan Pucci, Juan Castilla-Rho, and Darren Sinclair

23 Compliance and Enforcement: The Achilles Heel of French Water Policy 435
 Marielle Montginoul, Jean-Daniel Rinaudo, and Charlotte Alcouffe

24 Tracing the Impact of Agricultural Policies on Irrigation Water Demand and Groundwater Extraction in France 461
 Josselin Rouillard

25 Groundwater Management Lessons from Chile 481
 Guillermo Donoso, Elisabeth Lictévout, and Jean-Daniel Rinaudo

26 California’s 2014 Sustainable Groundwater Management Act – From the Back Seat to the Driver Seat in the (Inter)National Groundwater Sustainability Movement 511
 Thomas Harter

27 Changing from Unrestricted Access to Sustainable Abstraction Management Regimes: Lessons Learnt from France and Australia 537
 Jean-Daniel Rinaudo, Steve Barnett, and Cameron Holley

About the Editors

Steve Barnett is a Principal Hydrogeologist at the Water Science and Monitoring Branch of the Department for Environment and Water in South Australia. He has been involved in the investigation, monitoring and management of groundwater resources in SA for over 40 years and has contributed technical and policy input into ten groundwater management plans, which incorporate a variety of different aquifers and management issues. He is a past president of the Australian Chapter of the International Association of Hydrogeologists.

Cameron Holley is a professor at University of New South Wales Law and is a member of the Global Water Institute and Connected Waters Initiative, University of New South Wales Sydney. Cameron has worked closely with Australian and international government and non-government organisations on a range of water and natural resource management research projects. He currently holds ARC Discovery Grants (DP170100281 DP190101584) on Non-Urban Water Regulation and Integrating the Governance of Water and Coal Seam Gas that supported this chapter. He is an editorial board member on the *Environmental and Planning Law Journal* and in 2016 was the guest editor of a Special Issue (EPLJ Vol 33 Part 4), entitled Rethinking Water Law and Governance.

Marielle Montginoul is senior researcher in Economics at the National Research Institute for Agriculture, Food and Environment (INRAE – previously IRSTEA) and she is a member of the Joint Research Unit G-Eau. Her work focuses on understanding and modeling farmers and households’ water consumption behaviors. She more specifically studies instruments that can be used to reveal these behaviors when information is incomplete. Her research also focuses on economic tools to manage water withdrawals, with a focus on water pricing. She mobilizes a wide range of methodologies including surveys, experimental economics, and scenarios workshops. Marielle is member of the scientific council of the Rhone Méditerranée

and Corsica Water agency. She coordinates a Master in Social sciences applied to water management in Montpellier University.

Jean-Daniel Rinaudo is a researcher at Brgm, Montpellier University, where he coordinates the scientific programme on environmental and risk economics. Initially trained as an agricultural engineer (Montpellier SupAgro 1994), he specialised in agricultural and resource economics (PhD University of Auvergne, 2000). Prior to joining Brgm, he worked for the International Water Management Institute in Pakistan, where his research focused on the political economy of irrigation management reforms. His current research mainly focuses on the institutional economic dimension of groundwater management. Most of his research is conducted in France, but he also works in Morocco and Chile. He is currently developing new research activities in the field of natural disaster economics, focusing on the methods for assessing economic vulnerability and resilience. Dr. Jean Daniel Rinaudo is also a member of the Scientific Council of the Adour Garonne River basin agency.

Contributors

Charlotte Alcouffe INRAE – UMR G-EAU. Montpellier University, Montpellier, France

Luc Arnaud BRGM (French Geological Survey), Orléans, France

Pascal Billault Agence de l'Eau Loire Bretagne, Orléans, France

Elisabetta Carrara Bureau of Meteorology, Melbourne, VIC, Australia

Juan Castilla-Rho UTS (University of Technology Sydney), Sydney, NSW, Australia

Laurence Chery BRGM (French Geological Survey), Orléans, France

Pierre Le Cointe BRGM, Ramonville-Saint-Agne, France

Phil Commander Consultant, Perth, WA, Australia

Peter Cook Flinders University, Adelaide, SA, Australia

Roger Cranswick Department for Environment and Water, Adelaide, SA, Australia

Guillermo Donoso Harris Department of Agricultural Economics, Pontificia Universidad Católica de Chile, Santiago, Chile
Water Law and Management Center, Pontificia Universidad Católica de Chile, Santiago, Chile

Bruno de Grissac SMEGREG, Bordeaux, France

Olivier Douez BRGM (French Geological Survey), Bordeaux, France

Jean Eudes du Peuty EPTB Marais Poitevin, Luçon, France

Clive Hampton Water Corporation of Western Australia, Perth, WA, Australia

Megan Hancock Lane Department for Environment and Water, Adelaide, SA, Australia

Nikki Harrington Innovative Groundwater Solutions Pty Ltd (IGS), Victor Harbour, SA, Australia

Thomas Harter Department of Land, Air, and Water Resources, University of California, Davis, CA, USA

Amanda Kennedy Faculty of Law, Queensland University of Technology, Brisbane, QLD, Australia

Ann Kollmorgen Department of Environment, Land, Water and Planning, Melbourne, VIC, Australia

Frédéric Lapuyade SMEGREG, Bordeaux, France

Gaïa Lassaube Centre Emile Durkheim, Institut Français de Pondichery, Pondicherry, India

Daniel Lepercq CACG, Tarbes, France

Elisabeth Lictevout Universidad de Concepcion, Concepción, Chile Carpe Science, San Pedro de la Paz, Chile

Benjamin Lopez BRGM (French Geological Survey), Orléans, France

Julia De Luca Department of Environment Land Water and Planning (DELWP), Melbourne, VIC, Australia

Pierre Marchet Agence de l'Eau Adour Garonne, Toulouse, France

Jean-Christophe Maréchal BRGM, Montpellier University, Montpellier, France

Mal McGivern Water Corporation of Western Australia, Perth, WA, Australia

Tariro Mutongwizo University of New South Wales, Sydney, NSW, Australia

Rebecca Nelson Melbourne Law School, University of Melbourne, Melbourne, VIC, Australia

Vorlette Nuttinck Direction Départementale des Territoires de Tarn-et-Garonne, French Government, Montauban, France

Daniel Pierce Department for Environment and Water, Adelaide, SA, Australia

Jon Philippe Pigois Department of Water and Environmental Regulation, Perth, WA, Australia

Lindsay Preece Department of Water and Environmental Regulation, Perth, WA, Australia

Susan Pucci NSW Department of Planning, Industry and Environment – Water, Sydney, NSW, Australia

Gabriela Cuadrado Quesada Department of Integrated Water Systems and Governance, IHE-Delft Institute for Water Education, Delft, The Netherlands

Audrey Richard-Ferroudji French Institute of Pondicherry, Pondicherry, India
UMR G-EAU, Montpellier, France

Stuart Richardson CDM Smith, Adelaide, SA, Australia

Josselin Rouillard BRGM, Montpellier University, Montpellier, France

Marc Saltel BRGM (French Geological Survey), Bordeaux, France

Stephanie Schulte NSW Irrigators Council, Sydney, Australia

Ken Schuster Farmer, Founding Member of the Murrumbidgee Groundwater Preservation Association, Darlington Point, NSW, Australia

John Sharples Bureau of Meteorology, Melbourne, VIC, Australia

Craig T. Simmons National Centre for Groundwater Research and Training, Flinders University, Adelaide, SA, Australia

Darren Sinclair Institute for Governance and Policy Analysis (IGPA), University of Canberra, Canberra, Australia

Frederic Verley DREAL, French Government, Orléans, France

Glen Walker Grounded in Water, Mount Osmond, SA, Australia

David Williamson Department for Environment and Water, Mount Gambier, SA, Australia

Chapter 1

Sustainable Groundwater Management in France and Australia: Setting Extraction Limits, Allocating Rights and Reallocation



Cameron Holley, Jean-Daniel Rinaudo, Steve Barnett,
and Marielle Montginoul

Abstract This chapter briefly introduces the main policy developments from both France and Australia regarding groundwater management and their particular approach to setting caps, allocating rights and allowing reallocations. It then presents the objectives of the book and explores the book's contributions under four key themes, namely groundwater and policy approaches in France and Australia, capping water use and defining sustainable abstraction limits, reducing entitlements to sustainable limits, and comparisons between France, Australia and other international groundwater developments.

Keywords Groundwater · France · Australia · Capping resource use · Allocating use rights · Reallocation · Adaptation · Chile · USA

C. Holley (✉)

Faculty of Law, University of New South Wales Sydney, Sydney, NSW, Australia
e-mail: c.holley@unsw.edu.au

J.-D. Rinaudo

BRGM, Montpellier University, Montpellier, France

S. Barnett

Adelaide, SA, Australia

M. Montginoul

INRAE – UMR G-Eau, Montpellier University, Montpellier, France

© Springer Nature Switzerland AG 2020

J.-D. Rinaudo et al. (eds.), *Sustainable Groundwater Management*,
Global Issues in Water Policy 24, https://doi.org/10.1007/978-3-030-32766-8_1

1.1 Introduction

During the last three decades, economic development of both urban and rural areas has increasingly relied on groundwater resources, which supply water for around 40% of irrigated lands, half of all drinking water, and are impacted by the growth of unconventional oil and gas projects (WWAP, 2015; Holley and Kennedy, 2019). However, this development has often taken place in a context of “weak” governance (Faysse, Errahj, Imache, Kemmoun, & Labbaci, 2014), in which groundwater was often considered as an open access resource. In many regions around the world, individual water users acting independently according to their own self-interest, without considering the aggregate impact of their decisions on the sustainability of the resource, have depleted groundwater, illustrating the tragedy of the commons (Hardin, 1968). Due to excessive pumping, groundwater levels have been declining, affecting dependent ecosystems, in particular by reducing river base-flows, disconnecting rivers from aquifers and lowering water levels in wetlands (WWAP, 2015). Overdraft has led to land subsidence and increased cost of pumping, as well as irreversible deterioration of many aquifers through intrusion of saline or contaminated water from adjacent aquifers (FAO, 2016a; Fienen & Arshad, 2016; WWAP, 2015; Van der Gun, 2012). These trends have been documented in many semi-arid, but also temperate regions in Asia (China, India, Pakistan), America (Chile, the United States of America, Mexico), Europe (Spain), North-Africa and the Middle East (Morocco, Jordan) and to some extent, in both Australia and France.

While contributing to creating wealth and alleviating poverty in the short term, these problems arising from groundwater development could lead to the collapse of thriving agricultural economies which are strongly dependent on groundwater (Petit et al., 2017). These threats are a matter of increasing concern to many nation States that have supported agricultural development through subsidies and infrastructure development. Indeed, as many States and the global community now recognise (see e.g. Sustainable Development Goal 6), on-going groundwater overdraft could render these investments worthless and transform areas of former economic expansion into regions of poverty.

A critical issue for policy makers is ensuring that groundwater extraction is sustainable in the long term. Although there are large groundwater policy and governance gaps across the globe, where policies do not exist, attention is paid to models and success stories that could be replicated (FAO, 2016a; Molle & Closas, 2017). Many studies have been carried out into groundwater problems, and many technical solutions (e.g. recharge, water transfers, conjunctive use, water saving technologies) and institutional frameworks (e.g. collective and common pool resource approaches) (Giordano, 2009; Jakeman, Barreteau, Hunt, Rinaudo, & Ross, 2016; Ostrom, 1990; Van der Gun, 2012; Villholth, Lopez-Gunn, Conti, Garrido, & Van Der, 2017) have been proposed. Yet despite these institutional and technical tools, their actual implementation has remained a significant global challenge. As the FAO (2016b) has noted: “one thing is clear; it is not the formulation of laws and regulations that will make a difference, but their implementation and adoption ...”.

This edited collection accordingly provides insights by bringing together practitioners and academics to reflect on their experience with developing and implementing groundwater management policy. In this regard, the book focuses on a policy model and its implementation that a number of academics and international agencies have been promoting. This policy model consists of (i) capping total resource use, (ii) allocating use rights accordingly and (iii) defining rules to allow reallocation and adaptation to changing economic and climatic conditions. Capping consists of calculating and imposing a Sustainable Abstraction Limit (SAL), which when observed, guarantees the continuity of use for future generations and ensures the proper ecological functioning of groundwater dependent ecosystems such as streams and wetlands. The available resource defined by the SAL is then allocated to users via rights, which can either be individual or collective, defined in volume or pumping rate and taking the form of administrative permits, concessions or types of property rights. Those rights can be reallocated over time, based on either administrative procedures (e.g. waiting lists), market mechanisms (if rights are made tradable), or negotiated rules defined by users themselves (e.g. decentralized self-regulated management). This allows adaption of the initial allocation of rights in response to changing economic or demographic conditions, or to the exit or entry of users, with the primary objective of seeking maximum economic returns from use of the resource. Finally, rules are set-up to adjust water entitlements in the event of a reduction in the available resource.

This generic model underpins groundwater management policies implemented in a number of high or intermediate income countries such as Australia, Chile, the United States of America (particularly the Western United States), Spain, Mexico, and France. While this model is one that other countries, including less developed ones, could aspire to, it is important to highlight that it is not a rigid prescriptive model. It can be adapted to very diverse technical, social and political contexts and can accommodate different concepts of social justice, water rights, decentralisation and trade-offs between environment, economics and equity. It is equally important to note the difficulties likely to emerge during the implementation phase, whose duration is often measured in years, if not decades. This book highlights this diversity of implementation approaches, problems and successes, though a comparative analysis of several case studies in France and Australia, two countries which have a long history in groundwater management reforms and implementation.

In the early 1990's, both countries initiated a groundwater management policy reform which broadly followed the model presented above. As displayed in Figs. 1.1 and 1.2, both nations initially followed a broadly similar trajectory, that began with access regimes based around individual rights, before shifting in the twentieth century to the regulation and licensing of wells/bores, but with little consideration of sustainable extraction limits. It was during the late 1990's and early 2000's that both nations commenced major reforms based around the policy model of capping total resource use, allocating use rights and defining rules to allow reallocation and adaptation. Notwithstanding this commonality, as shown in Figs. 1.1 and 1.2 and throughout the book, both nations diverge in how this model was given effect in practice.

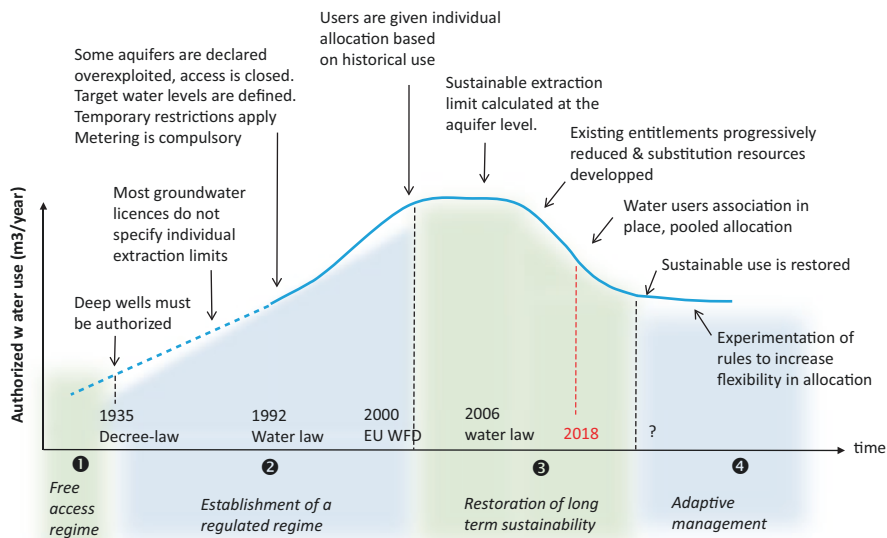


Fig. 1.1 The four policy phases for regulating groundwater abstraction in France

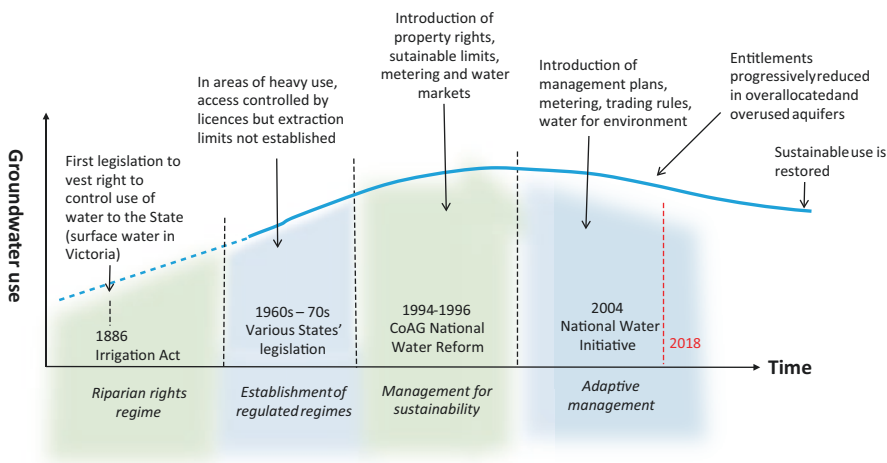


Fig. 1.2 The four policy phases for regulating groundwater abstraction in Australia

In the following discussion, we briefly introduce the main policy developments from both France and Australia regarding groundwater management and their particular approach to caps, rights and reallocations.

1.2 Groundwater Management Policies in France and Australia

1.2.1 Overview of the French Approach

In France, the historical evolution of groundwater development and management can be broken down into four major phases (see Fig. 1.1). The initial phase corresponds to a system of free access to the resource, in which landowners can freely appropriate the water located beneath their land. The proliferation of deep industrial boreholes and the rapid development of confined aquifers that occurred during the 1850's and early 1900's led to some occurrences of overexploitation. This threatened the resources regarded as being of strategic importance for supplying drinking water, which prompted the State to intervene.

The first groundwater legislation was subsequently passed in 1935. It involved setting up a permit system for wells and boreholes, which essentially aimed to control industrial use in order to protect the supply of drinking water. Between the end of the 1960s and the early 1990s, the increase in the number of agricultural boreholes, often tapping shallow aquifers, generated new cases of overexploitation and conflict over environmental protection issues. The 1992 Water Act provided a response to this crisis by strengthening the State provisions for controlling abstraction. In particular, it established the necessary conditions for volumetric management of water abstraction, including the obligation to record actual use (metering) and the allocation of individual abstraction quotas. Although the mechanisms were in place, overexploitation problems persisted due to over-allocation.

The third phase was initiated by European legislation, known as the Water Framework Directive. This Directive obliged member states to restore all their bodies of water to a satisfactory state in terms of quality and quantity. The French implementation strategy of that Directive was laid down in the 2006 Water Act which requires capping total abstraction and sharing the available resource among users. As the cap was lower than historical use in many groundwater and river basins, managers had to design rules to reduce entitlements. To do so, the 2006 Act encouraged the development of a collective approach to water allocation, notably through the creation of the Water Users' Associations (called OUGC). In the first step, this collective management was only implemented to manage agricultural users, which represent the highest number of users and frequently the highest share of resource use.

The final phase will involve developing new and flexible water management mechanisms capable of adapting to a rapidly changing economic and climatic environment.

1.2.2 Overview of the Australian Approach

Following thousands of years of Indigenous rules and concepts relating to water and the environment (Marshall, 2017), the transplantation of the Anglo common law riparian and capture rights granted landholders the ability to conditionally access and use water adjacent to and beneath their land. As demand for water by growing urban centres increased, the inadequacies of this approach became apparent. This prompted the first state legislation in 1886 which vested the right to the use, flow and the control of water in the state, marking the transition from rights to state legislative regimes (Gardner, Bartlett, Gray, & Nelson, 2017). Reflecting broadly similar developments in France, Australia's states progressively vested control over water in the Crown and abolished or displaced existing common law rights in response to increasing groundwater development in the 1960's and 1970's, creating a system of licencing (albeit one that did not pursue wide ranging caps on water use) (Holley & Sinclair, 2018).

Echoing comparable developments in France, Australia's modern water reform journey commenced in the early 1990's motivated by concerns about the efficiency and equity of water allocations and also with environmental sustainability. Under the Australian constitution, the states historically had primary responsibility for water management, but the initial reforms were founded on ideas of intergovernmental agreements and action through the Council of Australian Governments ('CoAG'). A national water framework was agreed to in 1994 (CoAG, 1994), closely followed by a similar 1996 Framework for Improved Groundwater Management.

These reforms created the emblematic aspect of Australia's approach, which is the creation of water rights (separated from land), within overarching sustainable limits set using scientific methods. Rules for the trading of water rights would support the intention that water would be used in the most efficient and productive way. The reforms also encouraged a system of regulatory enforcement. Perhaps the main contrast to the French approach is that the Australian policy model sets out aspirations for market-based reforms.

A subsequent 2004 Intergovernmental Agreement known as the National Water Initiative (NWI), consolidated the 1994 reforms and aimed to embed a nationally-compatible water market, progressively remove barriers to water-trading, facilitate efficient water use and address adjustment issues (Cwth of Aus., 2004). This next wave of reforms also aspired to return over-allocated or overused systems to environmentally-sustainable levels of extraction by encouraging the development

and finalisation of aquifer and catchment based statutory water allocation plans, and making statutory provision for environmental and other public benefit outcomes. Community engagement, partnerships and consultation throughout plan development and review was deemed essential to this adjustment process.

1.3 Objectives and Scope of the Book

The main objective of this book is to describe and analyse a variety of possible approaches and policy pathways to implement sustainable groundwater management, based on a comparative analysis of selected case studies in France and Australia. The book strictly focuses on quantitative management and does not cover in detail water quality or pollution management issues.

One of the specific features of the book is that a majority of the contributors are water professionals who have been involved for several decades in groundwater policy making, planning and implementation of management plans. Most of the contributors to this book participated in a French – Australian workshop organised in Montpellier (France) in October 2016 where they presented and discussed case studies that are covered in more detail in the following chapters and represent a significant contribution to the empirical water management literature that has not been published elsewhere, even in grey literature.

Recognising that groundwater has become an interdisciplinary subject (Van der Gun, 2012, p i) the originality of the book also lies in the different disciplinary perspectives covered in many chapters (hydrogeology, economics, planning, law and social sciences in particular).

In addition to the case studies, the book also presents the results of a comparative analysis conducted by these French and Australian water professionals, supported by a group of academics. This dialogue, initiated during the Montpellier workshop, led to the identification of similarities but also fundamental differences which are analysed and presented as alternative policy options in the conclusion of the book – these differences being mainly related to the role of the State, the community and market mechanisms in groundwater management. Given the importance of linking the experiences of Australia and France to other global developments, we also invited leading water academics to reflect on groundwater management experiences in other countries, in particular in Chile and the USA (particularly California).

1.4 Structure of the Book

The book's contributions can be divided into four main themes across a total of 27 chapters. Below is a brief overview of the themes and chapters.

1.4.1 Theme 1: Groundwater and Policy Approaches in France and Australia

The first selection of chapters provides background information on the French and Australian groundwater policy context at Federal/national levels as well as at river basin and catchment levels, where long term planning and implementation of groundwater policy actually takes place. The contributors provide a general assessment of the situation of groundwater depletion in both countries, with a focus on drought years, including the Millennium Drought in Australia and its impact on groundwater resource in the Murray Darling Basin. Groundwater professionals also describe how policies have progressively developed over the last 25 years, using primary information accumulated from their experience in practice, with the support of academic authors providing conceptual models for policy analysis.

Chapters 2, 3, 4 and 5 outline groundwater and management contexts in France. Maréchal and Rouillard (Chap. 2) describe the status of groundwater resources in France. The chapter highlights the geology and types of aquifers, as well as use of groundwater resources across domestic use, industry and agriculture. It notes that although France has not yet faced extreme cases of aquifer depletion, the long-term management challenges relate to the decrease of recharge due to climate change, sea level rise along the coast, and future change in groundwater use. It concludes by suggesting three core adaptation strategies.

In Chap. 3, Rinaudo examines the development of groundwater policy in France. The chapter maps a shift from private property to increasing State regulation of its use, broadly akin to similar developments in Australia discussed in Chap. 7. The chapter characterizes the development of the 2006 water law as constituting a clear break in French water policy, and examines the changes it introduced and the subsequent shift from a private to a common property regime.

The groundwater planning process in France resulting from the 2006 water law is analysed in Chap. 4. Rinaudo et al. explore the framework of local plans (SAGE) and strategic master plans for managing river basins (SDAGE). This chapter describes how strategic blueprints are formulated and implemented, including a historical analysis of 20 years of groundwater planning in the Adour-Garonne and Loire-Bretagne river basin districts.

Transitioning from the basin to the local aquifer level, Chap. 5 highlights lessons from 20 years of local volumetric groundwater management in the Beauce aquifer. In this chapter, Verley draws on personal experience to describe the evolution of management mechanisms for water abstraction, the characteristics of the water resource, its various uses, the problem of overexploitation and how the management plan evolved. The chapter also reflects on prospects for change.

Chapters 6, 7 and 8 shift the focus from the northern to the southern hemisphere, with Barnett et al. introducing groundwater in Australia (Chap. 6). The chapter charts the social, economic and environmental features of groundwater resources, while discussing the various types of aquifers, their development and future

management issues, including impacts of climate change, impacts of mining and declining government funding.

Building on the overview of Australia's groundwater resources, Nelson et al. (Chap. 7) chart the development of groundwater management in Australia, and how the experiences of other countries were taken into account. Recognising that the states and territories continue to be the primary managers of groundwater and are responsible for licensing processes and adopting legally enforceable plans to manage extraction, the chapter provides some case studies of differing approaches to groundwater management from different Australian states.

In Chap. 8, Walker et al. turn their attention to perhaps the most well known water management context in Australia, the Murray Darling Basin. The chapter describes the nature of groundwater systems in the Basin, noting that management of groundwater on a basin-scale had a lower priority compared to the more controversial surface water resources. It explains how a coordinated joint management plan for the increasingly important groundwater resources in the Basin was developed using a methodology to determine sustainable extraction limits across five states and territories. The chapter concludes its analysis by considering some of the challenges arising from this joint management approach.

Concluding this assessment of groundwater and policy approaches, Chaps. 9 and 10 focus on the dissemination and communication of groundwater information in both France and Australia. Sharples et al. (Chap. 9) use examples from Australia and France to discuss similarities and differences in the two nations' approaches to groundwater information systems, their history, and how these systems have been used to inform and improve groundwater management. A range of examples are explored including local management, national data standardization, online data sharing, and environmental impact assessment before summing up the future directions in this field.

Finally, in Chap. 10, Richard-Ferroudji and Lassaube draw on 11 case studies from France to report on a number of communication approaches and activities and how they were used to make groundwater "visible" for various stakeholders, including the general public, farmers and elected representatives. The chapter introduces a framework to analyse communication approaches and tools, before assessing the use of the tools, their benefits and limits, and concluding with recommendations.

1.4.2 Theme 2: Capping Water Use and Defining Sustainable Abstraction Limits

Building on the above overview, the second grouping of chapters examines the first part of the policy model, specifically looking at how water managers cap total water use by defining sustainable abstraction limits. These chapters investigate how this process is conceptually defined in the two countries, revealing the diversity of trade-offs made between environment and economic activities. They also provide a good

overview of the tools and groundwater models used to estimate extraction limits at different geographic and time scales, considering climate variability and uncertainties about future changes.

Chapter 11 commences with a review of conceptual approaches, methods and models used to assess abstraction limits for unconfined aquifers in France. Based on the analysis of over 30 studies, Arnaud shows that the estimation of this limit, called Maximum Permissible Volume (MPV) in France, is complicated by numerous uncertainties, data availability constraints and simplified assumptions made by hydrogeologists. These technical limitations of hydrogeological studies allow users to contest the MPV, which are often renegotiated.

Chapter 12 then focuses on the challenges of setting abstraction limits in confined aquifers, based on experiences from the deep confined aquifers in the Bordeaux region in France. In this chapter, Lapuyade et al. explore the historical development of cap setting, noting that risks of overexploitation of these resources was a driver for the implementation of specific regulations. Implementation of management policies and investigations to improve knowledge and develop groundwater flow models are also examined, and as the chapter explains, the local stakeholders involved in aquifer management employed these modelling tools to create the principles and policies for controlling groundwater-abstraction.

Chapter 13 (Le Cointe et al.) continues the focus on France with an analysis of the process and tools for determining sustainable annual allocations in the Tarn-et-Garonne alluvial aquifer. Using the previous history of events, the authors demonstrate the complexity and lengthy period of time required to develop a groundwater flow model that can be used by a government agency to support water allocation decisions. This chapter depicts a unique French water management approach where groundwater allocations for water users are updated every year, based on observed resource conditions. The chapter concludes with some unique insights on a shift in responsibility for the allocation process from the State to collective water user associations.

The evolution of the concept of sustainable development for groundwater resources in Australia is discussed in Chap. 14 by Pierce and Cook. Originally, the “safe yield” approach was employed whereby the upper limit for extraction was determined by the estimation of recharge. However, due to the difficulties and uncertainties in estimating recharge, and the fact that this approach does not allow for environmental uses of groundwater, management plans are increasingly moving toward the notion of acceptable impacts based on specified resource condition limits. They discuss in depth the methods used to evaluate four main areas of risk namely: storage capacity, groundwater dependent ecosystems, groundwater quality and aquifer integrity.

In Chap. 15, McGivern and Hampton provide a useful case study of a Western Australian approach to establish sustainable pumping limits. The chapter draws on insights from the management of an aquifer in Perth’s North West Urban Growth Corridor, where declining winter rainfalls, and an increase in average temperatures has complicated access to sustainable water resources for a fast growing population. McGivern examines how the sustainable yield of the aquifer was determined, and

argues that both groundwater flow models and simple spread sheet analytical models using representative hydraulic parameters can play important roles. The chapter also highlights how co-operation between water providers and regulators, and flexibility in the management approach, are important ingredients for successful outcomes.

The Barossa Valley wine region is the subject of Chap. 16 where Pierce et al. describe a new responsive and participatory management approach using resource condition limits. Consultations were held with a representative community group to determine the level of risk of adverse impacts occurring as a result of groundwater extraction. The impacts considered included changes in water levels, groundwater discharge to streams and the ingress of higher salinity groundwater. A groundwater flow model was then used to determine what extraction rates would result in acceptable levels of risk.

1.4.3 Theme 3: Reducing Entitlements to the Sustainable Limit

Despite efforts to allocate entitlements and set sustainable limits for extraction, a common challenge in many nations, including France and Australia, is over-allocation where the volume of entitlements exceeds the sustainable limit. The third theme of the book provides insights on how to reduce entitlements down to sustainable limits in over-allocated resources. A central theme across all these chapters is how water use rights are defined and allocated to users. The Australian chapters assess the results attained since management plans and water markets were introduced to reduce depletion and achieve sustainable abstractions limits. A comparison of the Australian and the French approaches reveals fundamental differences in the political and philosophical values in relation to water rights and to the role that user communities should play in reallocation.

In Chap. 17, Schulte and Cuadrado Quesada discuss Australia's policy pathways for reducing entitlements when groundwater resources are over-allocated. The chapter highlights definitional challenges that initially hampered progress within Australia's federated structure, before examining attempts to reduce over-allocation and over-use in Australia's numerous groundwater management plans. The chapter highlights the challenges that led to slower than expected progress in addressing over-allocation and over-use, as well as exploring the use of various mechanisms and tools, including phasing in allocation reductions and carry-over provisions, compulsory reductions of allocations with compensation, moratoriums, conjunctive forms of management through collective action, including donations of groundwater rights in return for surface-water rights, and water licence/entitlement purchases by governments in the water market.

Douez et al. (Chap. 18) turn their attention to approaches for developing alternative water resources as compensation for reduced groundwater entitlements.

In the case of the groundwater dependent Poitou Marshes in France, Douez et al. describe the relevant groundwater management policy and its response to the growth of irrigated agricultural as in other basins in central and western France (see Chaps. 5 and 13). The chapter examines the significant reduction in historical water entitlements and pinpoints the difficulties encountered in implementing this reduction in a context of extreme competition between economic uses (agriculture, urban uses, and tourism) and environmental objectives. The chapter also reports on the complexities in developing integrated water management plans for basins, providing insights on the requirements for success and exploring issues of coordination between the State, the local water management board and users associations where groundwater, rivers, wetlands, and canals are highly interdependent.

In Chap. 19, Barnett and Williamson examine approaches for allocation reductions and groundwater salinity management in South Australia. The chapter presents a case study of an exercise to reduce irrigation entitlements in an overallocated groundwater management area, driven by a longer-term risk to effective management of the resource. The chapter identifies a range of conditions that contributed to success, including establishing a good relationship and trust with the irrigators and staged reductions so that irrigators had time to adjust their operations.

Schuster et al. (Chap. 20) provide an additional example from Australia of approaches to reducing groundwater entitlements. Drawing on the history of events and the personal experience of Ken Schuster in the process of groundwater reductions in the Lower Murrumbidgee Groundwater Management Area, the case study provides lessons on water planning and policy approaches for reducing groundwater entitlements and the ensuing litigation by irrigators. The chapter points out the need to take local knowledge and concerns into account during the planning process, as well as providing adjustment mechanisms (e.g. economic compensation via Australia's Achieving Sustainable Groundwater Entitlements program) to ensure the long term sustainable management of groundwater.

In Chap. 21, De Luca and Sinclair offer some significant insights on Australia's innovative approach to managing entitlements, namely water markets. The chapter explores the challenges of using water markets to achieve sustainable water use, including physical and policy constraints that may determine where such markets operate. It examines how legal rights and water markets are used to manage groundwater in Victoria and other states throughout Australia, the success or otherwise of this policy approach, and its capacity to adapt to future pressures on water availability as a consequence of climate change.

The next two chapters address the issues of compliance and enforcement, an important component in ensuring any reduction in allocation is achieved in practice, and not undermined by groundwater theft or other illegal practices. In Chap. 22, Holley et al. draw on an empirical survey, regulator experiences and agent based modelling, to explore Australia's significant reform journey of compliance and enforcement policy over recent decades. They offer an analytical framework for studying groundwater compliance and enforcement and apply this frame to examine the experiences of a government regulator and water users. It concludes with a

summary of challenges and policy implications for groundwater compliance and enforcement regimes.

A similar set of compliance challenges emerge in Montginoul et al.'s analysis of groundwater regulation, compliance and enforcement in France (Chap. 23). They characterise compliance and enforcement as the "Achilles heel" of French groundwater policy. Drawing on a review of existing grey and scientific literature and a series of interviews conducted with enforcement officers in 16 French counties, the chapter examines the regulations governing groundwater abstraction, followed by a description of how the law enforcement agencies are organised and how they operate. Montginoul et al. analyse the infractions observed by regulators and the factors that may explain compliance and non-compliance, before highlighting the issues that limit the effectiveness of groundwater policy enforcement.

This grouping of chapters concludes with a discussion by Rouillard of the role of sectoral policies to restore groundwater balance (Chap. 24). Based on an analysis of European and French agricultural policies, Rouillard shows that sustainable groundwater quantitative management does not only depend on implementing the right water policy instruments. It also relies on enabling sectoral policies that work in synergy with water policy objectives.

1.4.4 Theme 4: France, Australia and International Comparisons

The last selection of chapters broadens the perspective by examining the groundwater management approaches in Chile and California. Based on two contrasting case studies, Donoso et al. (Chap. 25) describes the implementation of a relatively sophisticated groundwater management framework in Chile which relies on a unique combination of State intervention, market mechanism and collective management. The two case studies presented by the authors also highlight the existence of problems common with France and Australia, in particular the occurrence of over-allocation, the lack of State resources to enforce existing regulation and difficulties to obtain support from users to reduce abstraction when aquifers are overexploited. Their chapter also sheds light on the political dimension of groundwater management, unveiling how strategic behaviours may impact management decisions. In Chap. 26, Harter presents the ongoing groundwater policy reform in California, which promotes the development of sustainable groundwater management plans at the local level, with the State having substantial oversight over the planning process. Harter shows that many issues currently under discussion in California are similar to those which are still debated in France, Australia and Chile. In conclusion, Chap. 27 draws together the lessons from the above chapters to offer a "big picture" and comparative assessment of the Australian and French approach to the problem of groundwater depletion, and discusses which methods have been successful and which have not.