Water Resources: A New Water Architecture

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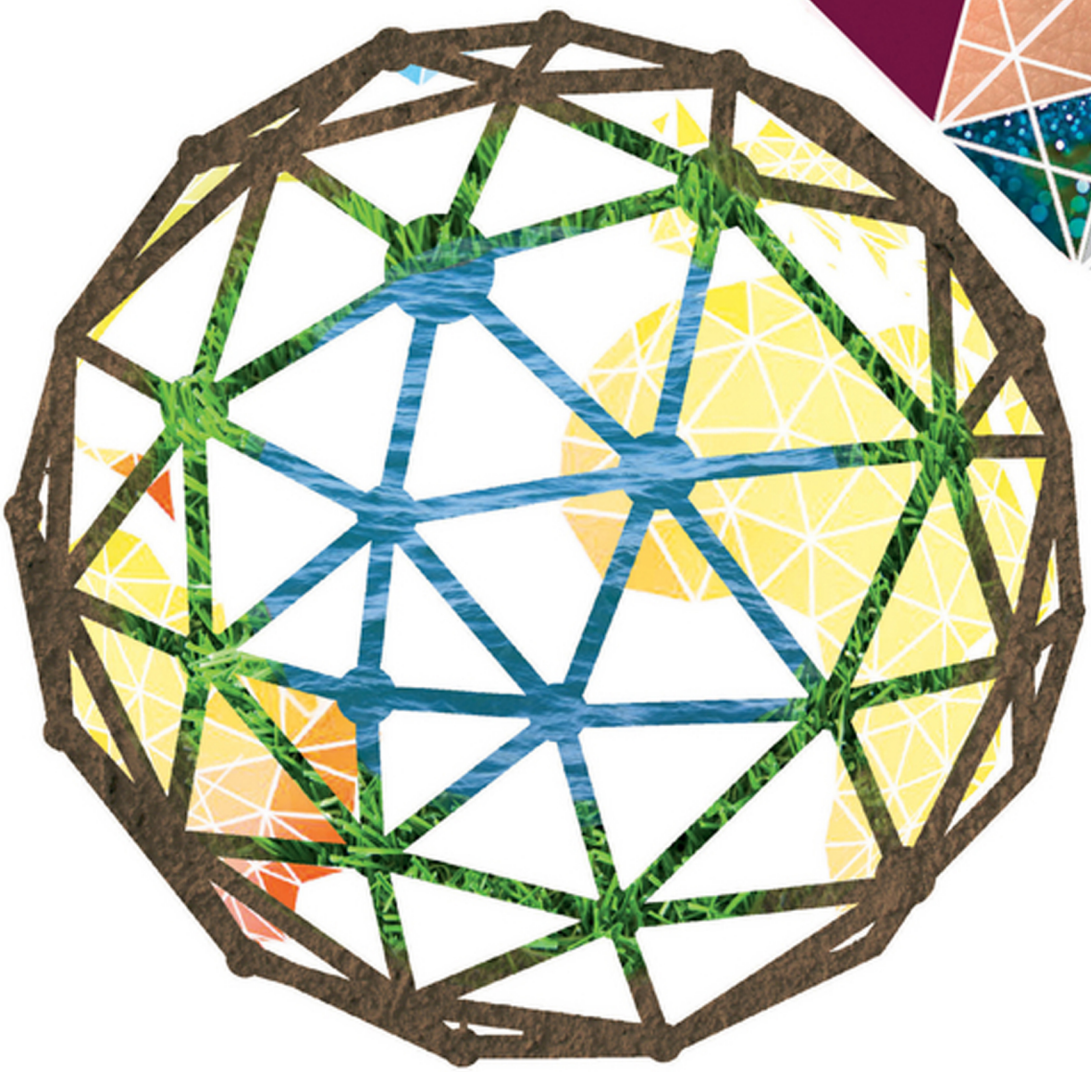

Challenges in Water Management

WILEY

Water Resources

Challenges in Water Management Series

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Titles in the series:

Urban Water Security
Robert C. Brears
2016
ISBN:978-1-119-13172-4

Water Resources: A New Water Architecture
Alexander Lane, Michael Norton and Sandra Ryan
2017
ISBN: 978-1-118-79390-9

Water Resources

A New Water Architecture

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WILEY Blackwell

This edition first published 2017

Registered Offices
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

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Library of Congress Cataloging-in-Publication Data
Names: Lane, Alexander, 1986- | Norton, Michael (Michael Robin), 1952- | Ryan, Sandra -1979
Title: Water Resources : A New Water Architecture / by Alexander Lane, Michael Norton, Sandra Ryan.
Description: Chichester, West Sussex : John Wiley & Sons, Inc., 2017. | Includes bibliographical references and index.
Identifiers: LCCN 2017007294 (print) | LCCN 2017008973 (ebook) | ISBN 9781118793909 (cloth) | ISBN 9781118793954 (Adobe PDF) | ISBN 9781118794074 (ePub)
Subjects: LCSH: Water-supply--Management. | Water demand management.
Classification: LCC TD215 .N67 2018 (print) | LCC TD215 (ebook) | DDC 333.91--dc23
LC record available at https://lccn.loc.gov/2017007294

Cover Design and Graphics: Courtesy of Lisa Mellis

Set in 10/12pt WarnockPro by SPi Global, Chennai, India

10 9 8 7 6 5 4 3 2 1

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Series Editor Foreword – Challenges in Water Management

The World Bank in 2014 noted:

'*Water is one of the most basic human needs. With impacts on agriculture, education, energy, health, gender equity, and livelihood, water management underlies the most basic development challenges. Water is under unprecedented pressures as growing populations and economies demand more of it. Practically every development challenge of the 21st century – food security, managing rapid urbanization, energy security, environmental protection, adapting to climate change – requires urgent attention to water resources management.*

Yet already, groundwater is being depleted faster than it is being replenished and worsening water quality degrades the environment and adds to costs. The pressures on water resources are expected to worsen because of climate change. There is ample evidence that climate change will increase hydrologic variability, resulting in extreme weather events such as droughts floods, and major storms. It will continue to have a profound impact on economies, health, lives, and livelihoods. The poorest people will suffer most.'

It is clear there are numerous challenges in water management in the 21st Century. In the 20th Century, most elements of water management had their own distinct set of organisations, skill sets, preferred approaches and professionals. The overlying issue of industrial pollution of water resources was managed from a 'point source' perspective.

However, it has become accepted that water management has to be seen from a holistic viewpoint and managed in an integrated manner. Our current key challenges include:

- The impact of climate change on water management, its many facets and challenges – extreme weather, developing resilience, storm-water management, future development and risks to infrastructure
- Implementing river basin/watershed/catchment management in a way that is effective and deliverable
- Water management and food and energy security
- The policy, legislation and regulatory framework that is required to rise to these challenges
- Social aspects of water management – equitable use and allocation of water resources, the potential for 'water wars', stakeholder engagement, valuing water and the ecosystems that depend upon it

This series highlights cutting-edge material in the global water management sector from a practitioner as well as an academic viewpoint. The issues covered in this series are of critical interest to advanced level undergraduates and Masters Students as well as industry, investors and the media.

Justin Taberham, CEnv
Series Editor
www.justintaberham.com

Foreword

I grew up in the valley of Wastwater and the River Irt in Cumbria in England. I was fascinated by water. Where did it come from? How was it that the Irt kept flowing even during dry weather? How did water influence the shape, width and depth of streams, rivers and lakes? Why was water such a haven for flora and fauna?

That fascination endured through my childhood and into my university education, where hydrology and geology were far and away my best subjects within a crammed civil engineering curriculum. I embarked upon a career in civil engineering, starting as a graduate trainee with a small English Water Board designing water supply infrastructure. My career subsequently took me far and wide to work on over 100 projects in more than 20 countries. The fascination with water has never faded, and I have contributed to solving problems to a wide range of water challenges, from water resources through water supply and wastewater, to managing floods and providing irrigation systems.

In 2008 my employer Halcrow Group Ltd entrusted me with a review of 'water scarcity' on the basis that it was perceived as a global mega trend that was going to impact most infrastructure and environment sectors in the early twenty-first century. I undertook that review with gusto and, along the way, learned more of the vital role that water plays in the biosphere; I was able to calibrate that learning against a background of having worked in a wide range of institutional settings.

It was during this time that the seeds of New Water Architecture (NWA) were sown in my mind, an idea that stemmed from Integrated Water Resources Management and was infused with elements of the emerging concepts of the water-food-energy system, virtual water and urban sustainability. My enthusiasm to develop new ways of thinking about water has been, and continues to be, shared by many colleagues, but two young people have stood out: Alex Lane at Halcrow as co-incubator of NWA; and Sandra Ryan at Amec Foster Wheeler as a kindred water spirit in an Oil & Gas-orientated company. When in 2012 I put to Sandra and Alex the idea of writing a book, they jumped at the opportunity. I am deeply grateful that they did.

Michael Norton
Long Newnton

Preface

We, the authors of this book, have been profoundly affected by our experiences in both our careers and our personal lives that are increasingly highlighting the very real problems of water scarcity, stress and mismanagement. Most worryingly, these problems appear largely disregarded or unheard of by those that hold the necessary power to take action.

We live and work in an age where we see water problems growing and accelerating; the pressure is tangible, and yet there remains inertia within organisations that have responsibilities and duties to govern and protect our water environment and its resources. Some of that inertia may be a consequence of the size and complexity of the challenges that face us. We suspect there is an element of 'heads buried in the sand', of hoping that water problems will somehow work themselves out while we continue to manage according to the *status quo*.

Recent years have seen a proliferation of advocacy groups and enlightened businesses that see things differently and argue that change is not just a good idea, but essential. Old, traditional concepts such as perceived 'rights' to unlimited water are being questioned and challenged by these groups and businesses, but governments seem to be lagging behind. New ways of thinking about water, such as water footprinting and virtual water, are gaining ground in terms of application and acceptance and are helping us to understand the complexity of our water problems. Slowly but surely, we believe a paradigm shift is occurring. Water management is no longer a responsibility ring-fenced by public authorities and taken for granted by water users. Businesses and their investors are experiencing the impacts of water stress and, gradually understanding the threats (and potential opportunities) these introduce, have taken the lead, beginning to embrace principles of water stewardship and increasingly forcing governments to follow suit.

Our careers have enabled us to work on many water projects, some at a very local scale. Such projects have given us a grassroots knowledge of hydrology and water management systems and an important understanding of the perceptions of, and demands for, water from businesses and industries. We have observed and are helping to direct the gradual change in the attitudes to water held by many corporations. We have also worked with national governments and with regional transboundary institutions and partnerships to analyse water issues at strategic international scales, and to assess the role of water in the development of national and international economic policy. We can see that the opportunity landscape for water professionals is beginning to look very different to that which has passed.

While we see the recent positive progress and the valuable lessons that are being learned, it is the numerous remaining barriers and obstacles that triggered us to write this book. The overlooked importance of water in so many of our daily activities – in the electricity and fuel we burn, the food we eat and the products we consume – is the dominant theme running through this book. Populations are changing, climates are evolving and our natural water systems are responding in complex and interlinked ways which we don't yet fully understand. 'More of the same' as a management approach is therefore not going to resolve our problems. While some of our current water resource management techniques and approaches are effective and, with continued improvement, can provide beneficial outcomes or even become cornerstones of a new water management paradigm, others have run their course and are now not fit to address the challenges we face. Having the courage to question the validity of well-established approaches and taking the necessary steps to enable change is difficult but necessary.

This book does not claim or intend to give all the answers. It presents the authors' collective views on how a new water management paradigm, a New Water Architecture, could look and feel. Its purpose is to stimulate the much-needed critical thinking on attitudes and approaches to water management that will drive real progress.

We believe that mankind must face up to the consequences that will be experienced if water management is not improved, if availability and access to safe and secure water resources does not improve, and if the detrimental impacts that arise from poor water management continue to become more widespread and intense. History presents us with several examples of civilisations whose collapses can be traced to water. People have always followed water and its associated riches and, while we may increasingly try to make water follow us, it is only resilient water management systems that will be able to sustain the global distribution of people in secure environments.

We urge all water professionals to measure their success in terms of their contribution to improving the water environment, in securing appropriate and fair allocation of water resources, and in increasing the perceived value of water in the eyes of all those with a stake in sustainable water management. By this, we are not referring to only political and corporate leaders, but to everyone.

Acknowledgements

We have received much direct and indirect support during the journey from initial idea to publication of this book.

First and foremost we wish to thank Professor John Bridgman of Birmingham University for suggesting to Wiley that we might be interested in writing such a book. Wiley asked a number of people to review the book proposal, and we wish to thank them. One of those reviewers has sadly since passed away, Professor Raúl Galindo of the Universidad Técnica Federico Santa María in Valparaiso Chile, and so we pass our thanks to his family.

We wish to thank Justin Taberham for his enthusiastic review of our final manuscript and his many suggestions of how we might disseminate our key messages. Thanks also to Laura Polito for her insight and advice on how to utilise the many media available to us to publicise and promote this book.

For production of the book we thank Lisa Mellis for her work with many of our original illustrations, copy-editor Elaine Rowan and all those too many to mention in Wiley who helped us on our journey.

Our families have played their part, not least putting up with times when we worked late or over the weekend as we tried to balance our day jobs with book writing. These include Shirley Norton, Cheryl and Peter Lane, and Caroline and Michael Ryan.

When we embarked upon the journey, our employers gave us permission to write this book: Amec Foster Wheeler for Sandra and Michael, and CH2M for Alexander. Our thanks go to them.

Finally, we wish to thank those friends, colleagues and others who have knowingly or unknowingly given inspiration to one of more of us, before and during the journey, including: Tony Allan, Tony Allum, Rodolfo Aradas, Frank Chasemore, Roger Falconer, Chris Fawcett, Mark Fletcher, Arjen Hoekstra, David Johnstone, Harlan Kelly, John Lawson, Bill McCall, Alex Mung, Ken Newnham, Isabella Polenghi-Gross, Susie Roy, John Readman, Rebekah Rice, Stacey Sabol, Barry Walton, Dominic Waughray, Marvin Williams and David Yaw.

List of Abbreviations

The following acronyms and abbreviations are used in this book.

Acronyms/Abbreviation	Term
AgMIP	Agricultural Model Inter-comparison and Improvement Project
ASR	Aquifer storage and recovery
AWS	Alliance for Water Stewardship
CAP	European Union Common Agricultural Policy
CAPEX	Capital expenditure
CBM	Coal-bed methane
CCS	Carbon capture and storage
CDP	Carbon Disclosure Project
CHP	Combined heat and power
CSO	Combined sewer overflow
CSP	Concentrated solar power
DEFRA	England and Wales Department for Environment, Food and Rural Affairs
EPA	US Environmental Protection Agency
EU	European Union
FAO	UN Food and Agriculture Organization
GCM	Global climate model
GDP	Gross domestic product
GM	Genetically modified
GWP	Global Water Partnership
ICDPR	International Commission for the Protection of the Danube River
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
MAR	Managed aquifer recharge
MDG	Millennium Development Goal
MENA	Middle East and North Africa
NETL	United States National Energy Technology Laboratory

Acronyms/Abbreviation	Term
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating expenditure
PPP	Public-private partnership
PV	Photovoltaic
PUB	Singapore Public Utilities Board
RCM	Regional climate model
RO	Reverse osmosis
RWR	Renewable water resource
SAR	Shallow aquifer recharge
SUS	Sustainable drainage systems
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UV	Ultra-violet
WASH	Water, sanitation and hygiene
WBCSD	World Business Council for Sustainable Development
WCD	World Commission on Dams
WEC	World Energy Council
WEF	World Economic Forum
WFN	Water Footprint Network
WHO	World Health Organization
WRG	World Resources Group
WRI	World Resources Institute

Units and Conversions

The following table provides conversions between the units of measurement commonly used in this book.

Unit	Conversion
1 megalitre (ML)	1,000,000 litres (L)
1 gigalitre (GL)	1,000 ML
1 cubic kilometre (km^3) or 1 cubic gigametre (Gm^3)	1,000,000,000 cubic metres (m^3)
1 m^3	1,000 L
1 km^3 or 1 Gm^3	1,000,000 ML

Glossary

Terms describing water resources

A variety of terms are used to describe water resources of one form or another and these are often used interchangeably. They are typically quantified as an annual total in cubic kilometres per year (km^3/yr). For ease of comparison between case studies, this book typically adopts the renewable water resource (RWR) term.

- *Renewable water resource*: The long-term average annual inflow and runoff that feed surface water catchment areas and groundwater aquifers.
- *Non-renewable water resource*: Groundwater bodies that have a negligible rate of recharge over the human time-scale.
- *Internal renewable water resource*: Volume of renewable water resource generated from precipitation within a defined territory.
- *External renewable water resource*: Volume of renewable water resource generated outside of a defined territory.
- *Natural renewable water resource*: The total amount of a country's surface and groundwater water resources (internal and external), generated through the hydrological cycle.
- *Non-conventional water resource*: Volume of water obtained through technologies such as desalination.
- *Actual renewable water resource*: The sum of internal renewable water resources and external renewable water resources.
- *Exploitable water resource*: That portion of water resources considered to be available for use. This varies from location to location dependent on physical, socioeconomic and environmental factors.
- *Blue water*: Fresh surface and groundwater, in other words, the water in freshwater lakes, rivers and aquifers.
- *Green water*: The precipitation on land that does not run off or recharge the groundwater, but is stored in the soil or temporarily stays on top of the soil or vegetation.
- *Grey water*: Freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards.
- *Virtual water*: Water consumed or polluted in order to produce a product, measured over its full production chain.
- *Improved drinking water source*: One that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter.

- *Improved sanitation facility*: One that hygienically separates human excreta from human contact.

Terms describing pressures on water resources

- *Water stress*: The effects felt, by humans and/or the environment, when the quantities and qualities of water available in a given location are insufficient to meet the demands placed upon them.
- *Water scarcity*: Water scarcity occurs when the demand for water is greater than the available resource. Water scarcity can be defined in three ways:
  1) *Physical water scarcity*: a physical shortage of water of an acceptable quality with respect to aggregate demand;
  2) *Infrastructural water scarcity*: where even though the actual renewable water resource may be sufficient to meet demand, there is inadequate infrastructure to get the water to where it is needed; and
  3) *Institutional water scarcity*: where institutions, legislation and/or regulation fail to ensure that water is supplied in an affordable and equitable manner. This type of water scarcity is sometimes referred to as economic water scarcity.
- *Water footprint*: The water footprint is an indicator of freshwater use that considers both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in terms of water volumes consumed (evaporated or incorporated into a product) and/or polluted per unit of time. A water footprint can be calculated for a particular product, for any well-defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organisation, private enterprise or economic sector). The water footprint is a geographically explicit indicator, showing not only volumes of water use and pollution but also the locations.
- *Direct water footprint*: The direct water footprint of a consumer or producer (or a group of consumers or producers) refers to the freshwater consumption and pollution that is associated with the water use by the consumer or producer.
- *Indirect water footprint*: The indirect water footprint of a consumer or producer refers to the freshwater consumption and pollution incurred in the consumption or production of products. It is equal to the sum of the water footprints of all products consumed by the consumer or of all (non-water) inputs used by the producer.

Terms describing different approaches to water management

- *Integrated Water Resource Management*: A process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment.

Terms describing the different ways in which people use water

- *Withdrawal/abstraction/extraction*: The taking of water from a natural source such as a river.
- *Consumed water*: The amount of water taken up in the process of a use and not returned to the environment.
- *Returned water*: The amount of water withdrawn from a source that is surplus to the amount needed for the use, or that water which is rejected or wasted, and that is returned to a waterbody.
- *Managed aquifer recharge*: The recharging of water into an underground aquifer for storage and subsequent withdrawal.
- *Aquifer storage and recovery*: One of the most common forms of managed aquifer recharge: injection of water into the target aquifer via a well.

Other terms

- *Hydroclimate*: The physical and chemical characteristics that define a particular aquatic habitat.
- *Primary energy source*: An energy source that has not undergone any transformative process. Primary energy sources can be renewable, such as wind and solar, or non-renewable such as coal, oil and natural gas.
- *Final energy*: That energy available to a user once a primary energy source has undergone conversion. Final energy types include electricity, gasoline and diesel oil.
- *Green infrastructure*: The use of natural ecosystems to deliver outcomes more commonly delivered by built (or grey) infrastructure.

Part I

Setting the Scene