Water Accounting

International Approaches to Policy and Decision-making

Edited by

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Acronyms and abbreviations

ABS	Australian Bureau of Statistics
ACCA	Association of Chartered Certified Accountants
AMD	acid mine drainage
ARJ	Acequia Real del Júcar
AW	Amatola Water Board
AWAS	Australian Water Accounting Standards
AWRC	Australian Water Resources Commission
bcm	billion cubic metres
BCM	Buffalo City Municipality
BoM	Bureau of Meteorology
cfs	cubic feet per second
CHJ	Confederación Hidrográfica del Júcar
CMA	Catchment Management Agency
CoAG	Council of Australian Governments
COD	chemical oxygen demand
CODWR	Colorado Division of Water Resources
CONAGUA	National Water Commission of Mexico
CPC	Central Product Classification
CPUC	California Public Utility Commission
CWAF	Chinese Water Accounting Framework
DB funds	defined benefit funds
DC funds	defined contribution funds
DRET	Department of Resources, Energy and Tourism
DF	depleted fraction
DNDE	Department of National Development and Energy
DSS	decision support system
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWR	California Department of Water Resources
ED AWAS 1	Exposure Draft of Australian Water Accounting Standard 1, The Preparation and Presentation of General Purpose Water Accounting Reports
EEA	European Environmental Agency
EPEA	Environment Protection Expenditure Accounts

ET	evapotranspiration
gpm	gallons per minute
GPWA	General Purpose Water Accounting
GRI	Global Reporting Initiative
HSEC	health, safety, environment and community
ICJ	International Court of Justice
ICMM	International Council of Mining and Minerals
INE	National Statistical Institute
INEGI	National Statistics Office of Mexico
INSEE	Institut National de la Statistique et des Etudes Economiques
IOSCO	International Organization of Securities Commissions
IPCC	Intergovernmental Panel on Climate Change
IRWD	Irvine Ranch Water District
IRWS	International Recommendations for Water Statistics
ISIC	International Standard Industrial Classification of All Economic Activities
ISO	International Organization for Standardization
IWMI	International Water Management Institute
IWMI WA	International Water Management Institute Water Accounting Framework
IWRM	integrated water resource management
JBA	Júcar Basin Authority
JWRS	Júcar Water Resources System
MAR	mean annual runoff
MCA	Minerals Council of Australia
MDB	Murray Darling basin
MDBA	Murray Darling Basin Authority
MDBC	Murray Darling Basin Commission
MDBCMC	Murray Darling Basin Commission Ministerial Council
MRC	Mekong River Commission
MRC-IS	Mekong River Commission Information System
MWR	Chinese Ministry of Water Resources
NAMEA	National Accounting Matrix with Environmental Accounts
NAMWA	National Accounting Matrix including Water Accounts
NBS	National Bureau of Statistics
NGO	non-governmental organization
NH-N	ammoniacal nitrogen
NRA	natural resource accounts
NWA	South African National Water Act
NWADp	National Water Accounting Development project

NWI	National Water Initiative
NWRS	South African National Water Resources Strategy
OECD	Organisation for Economic Co-operation and Development
PATRICAL	precipitation-runoff model integrated with water quality
PAWAS	Preliminary Australian Water Accounting Standard
PF	process fraction
SDAC	Standard Drainage Area Classification
SDL	sustainable diversion limit
SEEA	System of Environmental-Economic Accounting
SEEAW	System of Environmental-Economic Accounting for Water
SINA	National Water Information System (Mexico)
SNA	System of National Accounts
SUT	supply and use table
SWAC	Statement of Water Accounting Concept
SWRCB	California State Water Resources Control Board
TLM	The Living Murray programme
TPTC	Tripartite Permanent Technical Committee
UNECE	United Nations Economic Commission for Europe
UNSD	United Nations Statistical Division
UNWC	UN Convention on the Non-Navigational Uses of International Watercourses
USGS	United States Geological Survey
WA+	Water Accounting Plus
WACF	The Water Accounting Conceptual Framework for the Preparation and Presentation of General Purpose Water Accounting Reports
WASB	Water Accounting Standards Board, initially named the Water Accounting Development Committee
WEI	Water Exploitation Index
WFA	Water Footprint Accounting
WFD	European Water Framework Directive
WHO	World Health Organization
WISE	Water Information System for Europe
WMA	Water Management Area
WP	water productivity
WRS	water resources systems
WRSA	Water Resources Situation Assessment
WTW	water treatment works
WUA	Water User Association
WWTW	waste water treatment works

Foreword

Managing water resources intelligently requires decision-makers to be able to understand and measure the ultimate economic, social and environmental impacts of decisions about the management of water. This in turn requires sound data based on a conceptual framework to link water resources management to broader societal goals, and analytical systems to define and measure them. Just as GDP, the key indicator of national economic performance, is derived from the system of national economic accounts, so must the indicators of water performance be based on a system of water accounts.

This research book fills an important gap by examining the subject of water accounts in depth and by showing why and how water accounting is vital to decisions that will ensure that water and related resources are managed in a sustainable way. The book explains the role that water accounting can play in strengthening water policy and the water industry, in conflict mitigation and resolution, and in underpinning important economic, socio-political and environmental decisions. As such, it provides an in-depth overview of the state-of-the-art of a field of potentially great significance to water managers.

Consistent with its theme, this book is a truly collaborative project. Contributing authors are drawn from around the globe and from academic, practice and policy backgrounds in both water and financial reporting. They apply a range of theories and research methods to provide a wealth of thought leadership on issues faced at political, theoretical and practical levels, as countries and organizations use alternative water accounting systems to address critical issues.

Importantly, the book's contributing authors look at how and why particular approaches to water accounting have developed over time. They also examine the role of water accounting in transparent reporting that helps to establish property rights, mitigate or resolve water-related conflicts at international and national levels, protect the environment for future generations, demonstrate sound management of water to the advantage of an industry and aid investment decisions. Their exposition of the roles that water accounting can play in resolving regulatory, legal, political and social influences on water accounting policy settings or the effects of globalization helps in understanding diverse regulatory approaches.

One of the book's distinctive features is that its chapters are contemporary works written specifically to the theme of the role of water accounting. Strong efforts have been made to balance the chapters across continents and countries, and across academic, practitioner and policy perspectives. Moreover, these chapters have been analysed and debated by the team of authors to ensure that the book provides a coherent and comprehensive overview of issues relevant to the future.

This book, and the conference that led to it, provide new insights into the power of inter-disciplinary collaboration to resolve some of the world's most important economic, social, environmental, cultural and legal and policy issues. The book shows how high-quality information about water can be provided through water accounting, and has the potential to spawn a path-breaking strand of research that will yield lasting practical legacies.

I commend this book to all readers seeking insights into the role that water accounting can play in improving the management of water and related resources at all levels.

Professor Roberto Lenton
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University of Nebraska

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We also thank the authors for embracing the opportunity to contribute to a water accounting book, for sharing their knowledge and discipline expertise at our conference and for their highly constructive engagement throughout the journey to produce this book. We are pleased that many international friendships have been forged through the conference and book editing process.

We also thank Brad Potter for his assistance in reading through chapters and providing valuable suggestions for their development.

We are especially grateful for the understanding and support of our family and friends during those 'In a minute . . . I just want to finish this chapter' or 'In a week . . . I just need to discuss some issues at a water accounting conference' moments.

Production of this book would not have been as timely or as enjoyable without Leanne Reddan's constant, thoughtful executive assistance that went beyond the call of duty.

Jayne M Godfrey
Keryn Chalmers

Introduction

Keryn Chalmers and Jayne M Godfrey

One of the most pressing global issues of the twenty-first century is the scarcity of water of a quality appropriate to ensure economic, environmental and social sustainability. In addressing the issue through policy and management, key stakeholders recognize the critical importance of high-quality information. They also recognize the need for this information to be reported systematically to ensure that it is relevant, reliable, comparable over time and across entities, and understandable. But water scarcity has many implications, and it is possible that different reporting approaches, generally called water accounting systems, can be appropriate to addressing them.

In this book, international experts respond to the question: what role can water accounting play in resolving individual, organizational, industry, national and international economic, social and environmental issues? The book is born of a curiosity as to why different forms of water accounting have emerged, how they are utilized and what problems they can resolve. Our purpose in producing the book is to analyse some of the myriad issues that water accounting can help address, as perceived by authors from diverse disciplines and geographical regions.

As a discipline, water accounting and most of the various systems comprising it are in their infancy. But they are maturing fast. Given the early stage of the discipline's development, theoretical and practical questions need resolution to ensure that any individual system is rigorous enough and robust enough to endure in a form that is effective and efficient.

This book explores the roles that various water accounting systems can play in resolving a broad range of economic, environmental and social issues. It takes an international perspective, with content and authorship spanning the continents of Africa, America, Asia, Australia and Europe. It also addresses the role of water accounting in decision-making at individual, organizational, industry, national and international levels. Consistent with its global and multidisciplinary theme, the book examines the role of water accounting from the perspective of developed and developing countries, national and international law and policy, the environment, economic and sustainability issues and the role that water accounting can play in social, political and corporate contexts. It also reports analytical and empirical evidence of the efficacy of alternative specific systems of water accounting.

Authors bring academic, policy and practice perspectives. Consistent with an aim to draw out theoretical and practical issues, contributing authors include academics with expertise in relation to various aspects of financial accounting, geography, hydrology, economics, water accounting and water management and high-profile individuals with senior experience in water policy, water accounting and water management. The book melds both academic perspectives and regulatory insights with practical issues.

The book does not advocate or fully critique individual water accounting systems. Rather it exposes the systems for you, as readers, to form your judgements. In our concluding chapter, we provide a cursory overview of some of the comments that the authors have raised in relation to each other's chapters, and trust that they will be useful to your analysis.

ORIGINS

It would be reasonable to ask why we, as professors of financial accounting, chose to produce a book on water accounting. It would also be reasonable to ask what qualifies us to edit a book about water accounting.

To understand the answers to these questions, we take you back to our first engagement with the topic: it is 2006 and Australia is in the grips of its worst-ever drought. After two years of controversial negotiations, the Australian federal government and all state and territory governments have finally signed up to the National Water Initiative, a plan for the management of the nation's water resources. On the assumption that high-quality information is necessary to underpin sound decisions relating to water management, a key recommendation of that plan is the development and implementation of water accounting. However, the system of water accounting is not prescribed.

To capitalize on the potential to draw upon an existing rigorous and accepted system of reporting financial information, it was determined that the Water Accounting Development Committee, which has the responsibility to develop water accounting standards, should include a financial accountant. As researchers, we became involved in the subsequent water accounting activities in several ways. Because of her accounting theory research and financial accounting standard-setting experience, Jayne Godfrey became a member of the Water Accounting Development Committee and its successor, the Water Accounting Standards Board. Over the subsequent years these bodies developed a system of water accounting known as General Purpose Water Accounting. We both (Keryn Chalmers and Jayne Godfrey) worked with a fellow academic, Brad Potter, to draft the conceptual framework that underpins the work of the Water Accounting Development Committee and the Water Accounting Standards Board. In doing so, we have come to truly appreciate the significance of the work we are doing for future generations – not only because of the role water accounting can play to ameliorate some environmental degradation trends from poor water management, but also because of the role that reporting about water can play in understanding operating, legal and other risks for businesses, governments and industries and, indeed, for society as a whole.

Together with CPA Australia, the Institute of Chartered Accountants in Australia and our academic colleagues Brad Potter, Ken Trotman and Robyn Moroney, in 2008 we received Australian Research Council funding for a project to investigate the potential role of water accounting in an international context. The project required us to conduct experiments to assess the information content of water accounting reports for users of those reports. It also required us to organize a conference of potential contributors to a book on water accounting. Those potential contributors are all authors of chapters in this book.

The conference, 'International Water Accounting: Effective Management of a Scarce Resource', was held at the Monash Centre in Prato, Italy, in late 2010. The papers we discussed at the conference were the drafts of chapters appearing in this volume. The conference was a wonderful experience for us all and served one of the purposes of the grant: to generate greater international cross-disciplinary awareness of the scope of water accounting systems, their benefits and limitations and to provide an opportunity for intellectual and influential exchanges into the future. As such, we are extremely grateful to the Australian Research Council and to CPA Australia and the Institute of Chartered Accountants in Australia for the funding and other support that made the conference and the book possible.

From our brief four-year snapshot, we hope that you understand that we do not profess to be experts on all matters relating to water accounting. Rather, we profess to be fortunate to have worked with some of these experts and to be able to draw upon their knowledge and skills to produce this book. We hope that you will enjoy the book as much as we have enjoyed the journey leading to its production. We also hope that you learn, as we have, from reading the following chapters.

STRUCTURE AND THEMES

The book is divided into three thematic parts. The first part of the book describes several key water accounting systems that have developed to address a range of issues relating to water. Part II then examines whether two of the systems are capable of application in practice and evaluates them from both theoretical and practical perspectives. Part III extends the analysis to explore the role that water accounting in its various forms can play in addressing a range of serious institutional, state, national and international issues. In each part some of the chapters are written from the perspective of a particular country or state. However, the issues are never unique to that geographical region.

Part I Water Accounting Systems

Internationally, a range of methods of recording or reporting water information can be labelled 'water accounting'. Chapters in Part I consider several of the more prominent water accounting approaches that are being adopted, or are approaching adoption, for different but possibly complementary purposes.

Together with Maryanne Slattery, who has been intimately involved in most stages of water accounting development in Australia and extremely influential in orienting its approach towards financial accounting, we co-author Chapter 1, 'Beyond the hydrographers' legacy: water accounting in Australia'. This chapter describes General Purpose Water Accounting, a system developed in Australia, based upon the internationally accepted approach to financial reporting. General Purpose Water Accounting reports include a Statement of Physical Flows, akin to the cash flow statement of financial accounting. The Statement of Physical Flows shows how holdings of water moved during the reporting period. General Purpose Water Accounting reports also include accruals-based statements corresponding to the balance sheet and statement of comprehensive income: the Statement of Water Assets and Water Liabilities and the Statement of Changes in Water Assets and Water Liabilities respectively. The Statement of Water Assets and Water Liabilities reports water, and rights and other entitlements to water, as water assets. It also reports water liabilities, which are obligations to provide either water or water rights or other entitlements to other parties. The Statement of Changes in Water Assets and Water Liabilities shows movements in water assets and water liabilities during the reporting period.

General Purpose Water Accounting is designed to provide information that is useful to stakeholders, who otherwise could not command the information, for making decisions about the allocation of resources. These resource allocation decisions include, but are not limited to, assessments of accountability for water management and the consequent allocation of economic, environmental or social resources.

Around the same time that Australia was developing its General Purpose Water Accounting system, the United Nations was working on its System of Environmental-Economic Accounting for Water (SEEAW). This system records information about water in a manner similar to the way that most countries' national accounts record information about economic transactions. In Chapter 2, 'The System of Environmental-Economic Accounting for Water: development, implementation and use', Michael Vardon, Ricardo Martinez-Lugunes, Hong Gan and Michael Nagy describe the background and features of SEEAW, implementation of SEEAW and the challenges associated with that implementation. The chapter explains how SEEAW yields tables of cross-sectional or time-series data that can be extracted for research purposes or to prepare reports at national, industry, or organizational level. Most important, it explains how the system aims to link physical water information to social and environmental and economic information in a manner that can influence macroeconomic reform. It also discusses how water accounting can be strategically integrated into the routine duties of government agencies to make it more stable. The chapter discusses the extent to which the system has been globally accepted. Questions about the practicality of the system, because of issues obtaining data and then of obtaining data of sufficient reliability, are also addressed.

Water Footprint Accounting is the third water accounting system considered in Part I. Water Footprint Accounting aims to measure how much water is directly or indirectly consumed in producing particular products. Chapter 3 'Water Footprint Accounting' is authored by Arjen Y. Hoekstra, an ardent advocate of this system. Hoekstra explains that the water footprint concept aims to provide information that raises awareness of the extent to which the production of particular products is water-consuming relative to the production of others. Thus, the system is intended to inform consumption and production decisions based upon assessments of the impact on water consumption. It is analogous to the carbon footprint concept, one difference being that water, unlike carbon, is renewable. At the Prato conference for authors, there was much debate about this approach and in the conclusion chapter, we very briefly summarize that debate, particularly in relation to interpretation of the water footprint of a product produced using water of different qualities and sources and the practical implementation of the system.

In Chapter 4, 'Water accounting to assess use and productivity of water: evolution of a concept and new frontiers', Poolad Karimi, David Molden, Wim Bastiaanssen and Xueliang Cai write about water accounting at a catchment scale. This approach was developed at the International Water Management Institute (IWMI) and is labelled IWMI WA (for IWMI Water Accounting) in this book. Karimi et al. focus upon the use of accounting for water within a catchment, and how often, it is used. In particular, they explain the importance of accounting for depletion versus withdrawal of water within/from a confined geographic region, given cross-boundary water transfers that mean that water does not always return to the same place or time. Their purpose is to assess the productivity of water that spends some time in a catchment, in order to inform production approaches and economic and other decisions that should reflect an understanding of the renewable features of water use so that water is used most effectively and efficiently. While there are similarities with the General Purpose Water Accounting approach, IWMI WA focuses upon water itself rather than the rights and other claims to water and the productivity of that water use. The chapter examines the need for careful specification of the entity about which the water accounting report is prepared and the distinction between what water is recycled within a catchment and what water is subject to external sourcing or application.

The systems described in Part I reflect different approaches to informing some of the most important issues that the world is grappling with, the need to present that information in ways that will inform decisions and the need for data that can be used in research and to populate reports at macro, micro and product levels. They take very different approaches: General Purpose Water Accounting focuses upon the water report entity that either holds water or water rights, transfers water or water rights, or is obliged to deliver water or water rights. It addresses issues of not only what to report and how to measure information, but also how to disclose the information to be useful for decision-making. The decisions envisaged cover a range including economic, environmental, social and political. SEEAW was developed with the aim of providing a database of information that is useful for research purposes and for incorporation into reports that will guide decisions at a macro level. SEEAW information is also intended to be capable of being drilled down to state, catchment, industry and firm levels and possibly smaller units. Its purpose is primarily to inform economic, environmental and social decision-making. Water Footprint Accounting aims to provide information about products and the amount of water that was consumed in their production, regardless of the source of the water. The issues addressed by IWMI WA at a catchment scale concern assessments of the productivity of water in production, where water is sometimes recycled within the catchment, but sometimes transferred from external regions.

Part II Application and Evaluation of Water Accounting Systems

While Part I addresses the objectives of particular water accounting systems, Part II examines the practicality of producing reports that apply General Purpose Water Accounting principles or SEEAW principles. It does so across a range of international contexts. These chapters all demonstrate that it is possible to produce reports according to the systems and that the information is useful, but that data accuracy and reliability are an issue. While we do not investigate the matter fully within this volume, we expect that development of water accounting will, over time, foster the development of more rigorous metering and modelling of water volumes. This was certainly a sentiment expressed by participants in the 2010 conference.

In Chapter 5 'Water accounting in mining and minerals processing', Claire M. Cote, Jason Cummings, Chris J. Moran and Kristina Ringwood describe a system of water accounting that has been developed for the Australian mining industry with the support of its peak industry body, the Minerals Council of Australia. This system is a derivation of the General Purpose Water Accounting system described by Slattery et al. in Part I Chapter 1, modified to include additional reporting to satisfy Global Reporting Initiative disclosure requirements. Some mining companies have already started voluntarily adopting this system. Issues addressed in this chapter include determining what information is useful to external users of mining company water accounting reports and internally to mining companies. They also include the barriers to incorporating an industry reporting framework that is based upon General Purpose Water Accounting reports and how to modify or extend this system to a mining industry context. As with all of the systems described in Part I, a key issue, particularly in the early stages of systems development, concerns how to measure complex flows, particularly when water is used in several stages of production and evapotranspiration is significant.

An important feature of this chapter relative to others in the book is its explanation of the mining industry's motivations for adopting water accounting and for engaging early in the development of a system of water accounting. Recognizing that water accounting provides transparent reporting of information that otherwise is not systematically or comprehensively reported to external stakeholders, the authors describe these motivations as including the political benefits of both the industry and individual firms being seen as responsible users of water for both political and pragmatic reasons. The authors argue that water accounting that satisfies regulatory and perceived best practice reporting of responsible management of a resource that the industry is sometimes accused of wasting or polluting can provide information to assist the granting of a licence to operate. In particular, it can influence public opinion in ways that advantage the industry and firms by demonstrating that the industry uses and manages water more responsibly for the environment and for society than is otherwise perceived. A further, unstated, reason for early engagement with the development of General Purpose Water Accounting is undoubtedly to influence that system's development, rather than passively accept its requirements.

Part II Chapters 6 and 7 report pilot study applications of General Purpose Water Accounting principles in South Africa and Spain, respectively. In Chapter 6 'Potential for the application of General Purpose Water Accounting in South Africa', Denis A. Hughes, Esther Corral and Nikite W.J. Muller investigate whether the General Purpose Water Accounting system developed in Australia can be applied to a South African context. In particular, the authors report a pilot test of the system by a commercial water supplier, Amatola Water, in the Buffalo River catchment that supplies water to a socioeconomically diverse population. The chapter investigates whether data or systems constraints prevent implementation of the system.

The study finds that the proposed General Purpose Water Accounting system provides information that is potentially valuable to planning and water management, although not necessarily at a national level. It finds that the system could be useful for standardization of data sets and for transparent and understandable reporting that is useful to a range of users. It also identifies that for the catchment's particular circumstances, it is important to include a water quality dimension to the accounting and reporting. Furthermore, it identifies that there are sufficient data and systems sophistication to implement a system that enables assessments of water policy implications and can assist reconciliation studies. The chapter investigates implementation barriers, including data quality, and touches on the socioeconomic effects of water accounting using the proposed General Purpose Water Accounting system.

Application of the General Purpose Water Accounting system in a Spanish context is described and analysed by Joaquín Andreu, Andrea Momblanch, Javier Paredes, Miguel Ángel Pérez and Abel Solera, in Chapter 7 'Potential role of standardized water accounting in Spanish basins'. Among other matters, this chapter investigates the role of hydrological modelling tools in providing the basis for measures reported in General Purpose Water Accounting reports for the Júcar Water Resource

System in Spain. The chapter concludes that General Purpose Water Accounting can be a powerful tool to improve transparency of water management. It also identifies some issues in implementation based upon the scope of water accounting and data availability. As noted by participants at the Prato conference, a strength of this chapter is that it identifies the ability of the General Purpose Water Accounting system to identify information that managers should attempt to collect more carefully, or to more accurately measure or refine. This is a benefit, internally, of the system, but also reflects an issue for external reporting: when the system identifies very large unaccounted-for differences between identified and calculated/estimated water balances, this creates a credibility issue for either management or the reporting system. As such, the authors suggest a need to restrict the scope of water accounting to a physical domain where storages and flows are well measured or estimated, while simultaneously working to improve measurement and estimation.

Chapter 8 'Development and application of the System of Environmental-Economic Accounting for Water in China' describes China's experience in implementing its version of SEEAW. Hong Gan, Yu Wang, Qiong Lu, Michael Vardon and Qin Changhai explain how the Chinese Ministry of Water Resources, with assistance from the National Bureau of Statistics and the United Nations Statistics Division, developed a water accounting framework based on SEEAW but adapted to Chinese circumstances. This involved a whole-of-China survey of water by the Ministry and significant provincial and agency collaborations. The primary purpose of SEEAW has been internal water management (in contrast to the external focus of General Purpose Water Accounting) and the development of water accounting is playing an important role in strengthening water resources management in China, particularly by enabling the construction of a range of indicators for use by decision-makers. The chapter identifies challenges of data availability, data reliability (particularly in relation to groundwater) and the need for cooperation between organizational units if SEEAW, or indeed any water accounting system, is to be effective at a national level.

The final chapter in Part II, Chapter 9 'Two perspectives of water resource accounting: comparing the Australian and the United Nations approaches' by Eric Mungatana and Rashid Hassan, addresses whether water resources policy and management can be improved by using either or both SEEAW and General Purpose Water Accounting frameworks. Key features of this chapter include identification of the political nature of water accounting and the complementary nature of the systems in enhancing water resource management. The chapter identifies the perceived differing objectives of the systems. General Purpose Water Accounting is a communication and accountability tool, whereas SEEAW serves to combine physical water information with financial indicators to inform the understanding of environmental-economic information. The authors identify the strength of General Purpose Water Accounting as providing information for project evaluation and planning purposes. On the other hand, given that SEEAW aggregates information at a national level, it is targeted more at economic modelling and policy analysis.

Part III Contemporary Issues Addressed by Water Accounting

Part III investigates the roles that various systems of water accounting can play in conflict mitigation and dispute resolution within and across state and national boundaries and across time. At the extreme, this refers to mitigation and resolution of what some would argue are the greatest threats to national and international security: water wars. If the same rigorous approach to identifying, measuring and reporting water balances and trans-border flows, rights to water and obligations to deliver water is adopted and understood by parties engaged in transactions that have potential to generate conflict, the shared understanding reduces information asymmetry. In turn, this produces clarity in relation to the exercise of property rights as well as in relation to social and equity impacts of water movements and transactions. It will also provide information to facilitate longer-term water management decision-making for current and future generations' access to this scarce resource.

In Chapter 10 'The impossible planetary trust: intergenerational equity, long-term investments and water governance and regulation', Gordon L. Clark and Claire Woods explore how climate change intersects with intergenerational equity and how important it is that institutions and organizations make decisions for the welfare of future generations. The conflict they study is intergenerational: decisions of the current generation affect future generations. Importantly, they recognize that even long-term institutions fail to meet long-term needs because they are not willing to sacrifice short-term beneficiary needs. To govern for the future and deliver intergenerational equitable outcomes, the authors propose an independent planetary trust model for resource management. Looking through the planetary trust lens, they discuss water management in Australia, in particular the governance and decision-making of the Murray Darling Basin Authority. The case study highlights the conflicts between current and future users of water and the significance of good governance structures and information for governance and risk management. Water accounting, if derived from trusted information sources, will play a vital role in protecting the environment for future generations.

The quality of governance as an important determinant of water resource sustainability is a theme continued by Muller in Chapter 11 'Water accounting, corporate sustainability and the public interest'. In considering how water accounting can deliver effective water resource management, Mike Muller contemplates who is accounting to whom and for what. Achieving the optimal use of water in the public interest is inherently difficult considering the differing objectives of the actors involved (for example, public policy, corporate and environmental advocacy actors) and the scales, contexts and power mode in which they operate. Any water accounting system needs to be cognizant of such complexity and be capable of delivering information that is relevant, yet neutral. A water accounting system that does so will contribute to sustainable management; one that does not will result in sub-optimal water resource management decision-making.

In Chapter 12 'Water accounting and conflict mitigation', Lise Pretorius and Anthony Turton discuss the role for water accounting in the avoidance and resolution of water disputes. Critical in addressing this issue is understanding water risk. The chapter identifies eight water risk categories applicable to water and applies this risk model to the firm and other level units of analysis. General Purpose Water Accounting, by quantifying flows and stocks, can provide information to inform the risk assessment and thereby introduce an element of certainty into the risk model application. More informed risk assessment should result in more informed decision-making. Pretorius and Turton conclude that General Purpose Water Accounting has the capacity to inform sustainable water reform and mitigate conflict. They also explain a role for water footprint in revealing risk.

The role for water accounting in avoiding and resolving international water disputes is further explored in Chapter 13 'The role of a water accounting system in the avoidance and resolution of international water disputes'. Similar to Pretorius and Turton, Andrew Allan concludes that water accounting does have a role to play in resolving and avoiding transboundary watercourse conflicts. With an expertise in water conventions and treaties around the globe, Allan argues that the collection and regular exchange and communication of data promotes cooperation that at the very least should assist in determining whether or not the use of a transboundary watercourse is equitable and reasonable. However, the chapter stresses that the significance of the role that water accounting can play will be undermined in the absence of harmonized nomenclature, data collection methodologies and standardized reporting. Allan draws an analogy between water accounting and financial accounting to conclude that, just as globalization of financial accounting through International Financial Reporting Standards has assisted the resolution of international financial conflicts, a globalized water accounting system could reduce conflicts related to water.

Chapter 14 'Water accounting issues in California', is authored by Jay R. Lund. Quoting Lord Kelvin, 'if you cannot measure it, you cannot improve it', Lund reminds us that water accounting systems serve to improve the management of water resources. He also reminds us that water accounting has always been fundamental to managing water under conditions of scarcity. However, it is largely incapable of perfection in practice, particularly at larger regional scales involving more complex hydrologic interactions. The chapter uses a Californian context to review aspects of water accounting and discuss opportunities and prospects for its further development in this US state. Existing water accounting in California is described as 'sparse and rudimentary'. This, combined with an expanding population with increasing and diverse water demands, will demand a more robust and transparent system of accounting. It will be interesting to observe if political, institutional and practical impediments can be overcome to deliver a more desirable water accounting system. The chapter makes an important distinction between water accounting and measurement. While water measurement helps support water accounting, water accounting does not require water measurement if it is impractical to do so. However, with advances in computer modelling, water measurement impracticalities will become less frequent.

In the final chapter of Part III, 'Accounting for water rights in the western United States', Mark Squillace applies the Lund and Muller analyses to highlight the inaccuracy of various measurement techniques applied to water diversions and storages, the personal incentives that can lead to measurement error perpetuation and the individual and aggregate effects of measurement error. He explains how the aggregation of small individual property rights measurement errors can give rise to highly biased measures with severe water appropriation for the environment and for social well-being. Squillace's analysis covers technical, policy and governance measurement accuracy issues. It offers insights into how information about water diversions and use might be made more accurate and how that information might be used to promote a better system for managing water.

CONCLUSION

It is impossible to overestimate the importance of water to the economy, the environment, society and to the very survival of life on our planet as we know it. With competition for water growing, the need to account for how it is sourced and distributed will only increase. Water accounting has grown out of a demand for information to provide accountability and to assist in decision-making. It is important to acknowledge that in isolation, water accounting will not resolve any water crisis. It is a decision-making tool, not a solution. However, it can play a vital part in the resolution of economic, environmental, social and other issues. After all, good decisions are generally underpinned by good information.

We trust that you will enjoy reading this book and that it will afford insights into the critical role that water accounting can play at international, national and organizational levels. We also take this opportunity to thank our contributing authors for sharing their insights, expertise and their passion for an emerging discipline with us and with you, the reader.

PART I

Water accounting systems

1. Beyond the hydrographers' legacy: water accounting in Australia

Maryanne Slattery, Keryn Chalmers and Jayne M Godfrey

INTRODUCTION

Australia's creation as a nation of federated states and territories in 1901 occurred during a period of intense water scarcity and nearly stalled on the issue of how to equitably share the Murray River system across three states. More than a century later, one of the most recent reforms is the development of a system of water accounting that incorporates aspects of accounting, engineering, hydrology and other water-related disciplines. This chapter explores the reasons why Australia is taking an internationally leading role in developing this General Purpose Water Accounting system, which is directed towards providing information that supports important economic, social, environmental and other decisions. It discusses the development of the system and identifies further developments required to enable General Purpose Water Accounting to fulfil its objective of providing information useful for decision-making. These developments include the establishment of a regulatory framework, the development of reporting standards and the building of capacity in this discipline through research and training. Such developments will enhance the quality of information relating to water report entities. Thereby, they should facilitate more informed decision-making, thus reducing risks and even potentially preventing or mitigating future water crises.

Whilst the management of water and accountability for its management are relevant across Australia, they are arguably most salient in the Murray Darling Basin (MDB). The MDB covers approximately 1 million square kilometres (equivalent to the size of South Africa), in the country's southeast. The main rivers in this area are the Murray and Darling, each with many tributaries. The Murray forms the boundary between the states of New South Wales and Victoria and flows into South Australia before flowing out to the Southern Ocean. The Darling's origins are in southeastern Queensland, and it flows through western New South Wales, joining the Murray at Wentworth, in southwestern New South Wales. The MDB is home to 2.1 million of Australia's 22.5 million people, with an estimated further 1.3 million people dependent on its water resources (MDBA 2010) and produces approximately 40 per cent of Australia's food. The MDB has approximately 30 000 wetlands, 16 of which are listed under the Ramsar Convention of Wetlands of Importance. It receives an annual average rainfall of about 480 ml (millilitres), 90 per cent of which is consumed as evapotranspiration (Qureshi et al. 2004).

The MDB crosses five states and territories, and is jointly managed by the governments of New South Wales, Victoria, South Australia, Queensland, Australian Capital Territory and the Commonwealth, through complex, cooperative governance arrangements that have evolved since Federation.[1] The federal government also plays an important role in the wider coordination of Australia's water policy reform. Because of the critical importance of the MDB to Australia, the evolution and justification of water accounting in Australia is mostly explored in this chapter through issues relating to the MDB.

CONTEXT

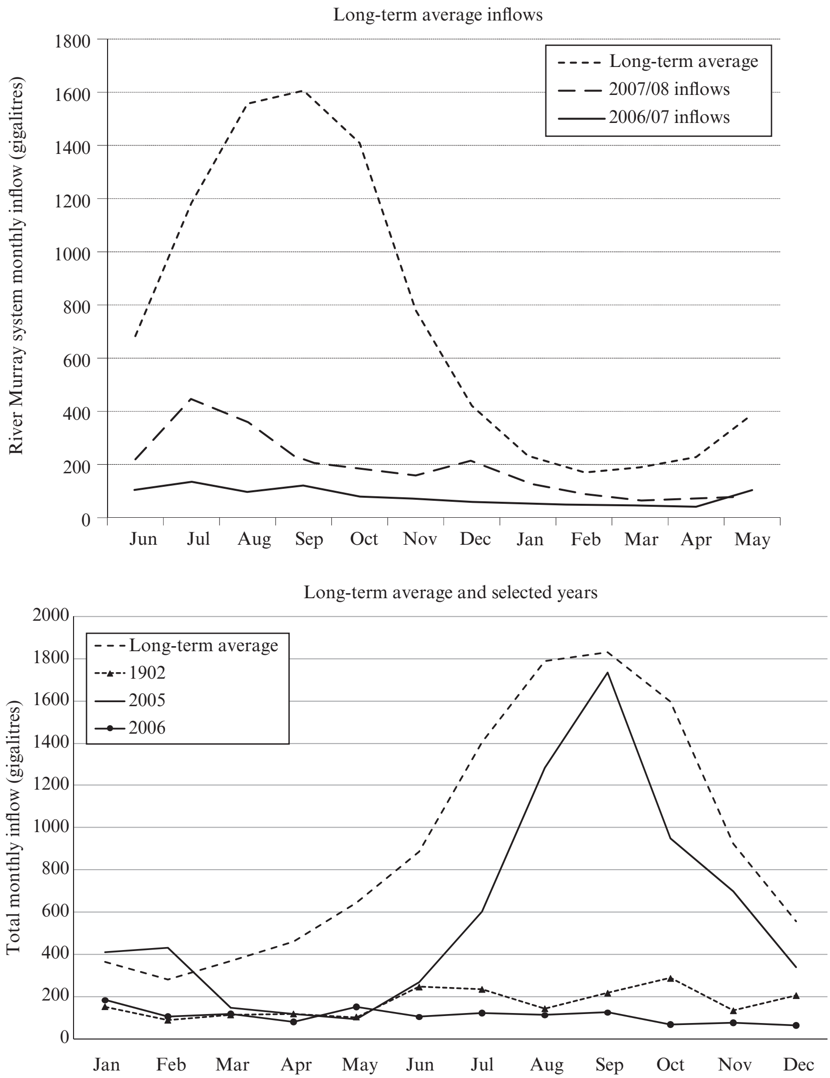
Water, and the sharing of water, is a central tenet in Australia's modern history. This history began with European settlement in 1788, following at least 50 000 years of indigenous Australian co-existence with the Australian landscape. Australia is the driest inhabited continent in the world by unit area, but has the highest per capita water availability and the highest per capita water use (CSIRO 2008). Australia is subject to significant rainfall variability: seasonally, yearly and across the continent, as is vividly demonstrated by the recent decade-long drought followed by widespread flooding.[2] It is also subject to periods of extended drought, typically heralded by El Niño conditions in the Pacific, followed by wet sequences, coinciding with La Niña and Indian Ocean dipole events. Rainfall and hydrographical variability are expected to be exacerbated by climate change. Australia's hydrographical variability has shaped, and will continue to shape, Australians' interaction with the natural environment.

Australia's hydrographical variability has repeatedly reined in the modern Australian psyche of 'boundless plains to share'[3] (Close and McLeod 2000). Initial European settlement in Australia was restricted to the area east of the Great Dividing Range[4] until 1813. Thereafter, the passage through the Great Dividing Range allowed settlement into the hinterland. By the 1850s the fledgling non-indigenous Australian population (less than 500 000) had established farming throughout the colonies (now states) of New South Wales, Victoria and South Australia. The expansions of agriculture during the mid- to late 1800s occurred during a significant wet sequence. Severe drought from 1895 to 1906 then forced a retreat of settlement from central and western South Australia. Grand abandoned station homesteads in South Australia from this period lie vacant to this day, rattling with the ghosts of drought and crushed hope. That drought also highlighted the significant stress on the River Murray system due to irrigation extraction. Named the 'Federation drought' it was one catalyst for the separate sovereign colonies combining to create the federated nation state of Australia in 1901. Under the Australian constitution, water remained vested under state (not Commonwealth) control. After formal water sharing agreements struck between the three southern states on the Murray, it has been necessary to account for water use to determine how water is shared between states.

The 1950s were a wet sequence and in 1956 inflows into the MDB were estimated at 117 907 GL (gigalitres), compared with the long-term average of 31 800 GL. Public policy at that time reflected the view that natural resources, including water, should be exploited to realize economic potential. In the absence of understanding of the environment's fragile capacity to sustain water extractions, water resources were developed and irrigation industries such as dairying, rice, horticulture and viticulture were promoted. For example, soldier settlement schemes gifted land (with embedded water rights) in the lower Murray Darling to returning World War II soldiers. A wave of European immigrants also moved into these areas. The irrigation districts were expanded along the Murray, the Darling and accompanying tributaries. The consequences of the subsequent over-allocation of the MDB waters remain today.

Following a wet reprieve in the 1990s, Australia again experienced a record-breaking drought in the first decade of the 2000s, out-rivalling the Federation drought. It featured a double El Niño uninterrupted by a La Niña event. Annual streamflow declined by 44 per cent compared with the long-term average. This represented a more significant decline than the 23 per cent during the World War II drought and the 27 per cent during the Federation drought (CSIRO 2010). Figure 1.1 shows the inflows into the River Murray for 2006 against 1902 (previous lowest inflows on record) and the long-term average (MDBC 2006).

Public and stakeholder scrutiny of water availability and the sharing of water against existing rights were understandably acute during this time. In 2006, for the first time the water sharing arrangements between the states under the Murray Darling Basin Agreement, which had been in existence since the 1915 River Murray Waters Agreement, were no longer



Source: Murray Darling Basin Commission (2006).

Figure 1.1 Inflows to the River Murray

capable of securing water for human needs along the River Murray.[5] In 2006 irrigator allocations were nil in several irrigation districts along the Murray. Further, an unprecedented situation occurred in 2006 when New South Wales and South Australia were unable to honour water allocations that had already been announced (ibid.). Irrigators had already selected and planted crops for the upcoming season based on their claims to water showing in their allocation accounts, portions of which were subsequently frozen. The need to account for how water was shared and managed, and the accountability of water managers was never more evident than during this period.

One problem faced by early irrigators was that water was available at the wrong time of the year: in winter and spring, and typically not available when needed in summer and autumn. To overcome this, a series of large dams was built along the River Murray and its tributaries during the twentieth century, enabling river managers to capture water when it was available and to deliver when needed. The dams also provided a level of drought proofing for the system. Australia now has the highest water storage capacity per capita in the world (Smith 1998).

Continuous accounting was introduced in 1983, whereby each state's share in the storage at the end of the irrigation season was maintained into the subsequent year, rather than the previous method of automatically reverting to equal sharing between New South Wales and Victoria (Connell 2007). This concept of accruals (continuous accounting) subsequently became available to irrigators with individual allocation accounts able to be carried forward into the next water year, subject to storage space.

ACCOUNTING WITHIN WATER REFORM

The extent of the Murray system over-allocation became obvious by the early 1990s. Extractions had tripled in the 50 years to 1994 (Close and McLeod 2000) and an audit of water use in the MDB in 1995 showed that the median annual flow at the Murray mouth was 21 per cent of natural flows (Murray–Darling Basin Ministerial Council 1995). In 1995 the partner governments agreed, by consensus, to cap surfacewater extractions in the MDB. Water extraction volumes by valley are determined and audited annually and compared against a seasonally adjusted cap.

The need for an ambitious programme of national water reform was agreed by the Council of Australian Governments (CoAG) in 1994. This agreement was followed by and reinforced by the Intergovernmental Agreement to the National Water Initiative (NWI), which was signed by the Commonwealth, state and territory governments between 2004 and 2006. The NWI outlines eight areas of reform to achieve its stated objective of 'a nationally-compatible, market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes' (CoAG 2004, p. 3). The eight areas of reform outlined in section 24 of the NWI are: (1) Water Access Entitlements and Planning Framework; (2) Water Markets and Trading; (3) Best Practice Water Pricing; (4) Integrated Management of Water for Environmental and Other Public Benefit Outcomes; (5) Water Resource Accounting; (6) Urban Water Reform; (7) Knowledge and Capacity Building; and (8) Community Partnerships and Adjustment.

The NWI gave additional, formal momentum to the development of water resource accounting in Australia. Specifically:

> the outcome of water accounting is to ensure that adequate measurement and reporting systems are in place in all jurisdictions, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recovered and managed for environmental and other public benefit outcomes. (Ibid., para. 80)

Important to the development of water accounting is the fact that it can be considered as a support mechanism for, and integral to, the other reform areas, such as water markets. Similarly, the other reforms, such as investment in metering, are fundamental to the implementation of water accounting and the relevance and faithfulness of water accounting information.[6]

Water markets allow trade of water entitlements (share of the resource) and water allocations (water made available annually against the entitlement). This allows water to move to its highest value use. Many different participants use the market to mitigate risk. Irrigators with permanent operations, such as horticulture or dairy, buy allocations in dry years to maintain operations. Irrigators base annual crop decisions on the expected price, which is based on availability of water. This is becoming increasingly sophisticated and can be linked to relevant commodity markets. For example, the estimated water price can be an important input into the cost of cotton futures. Some regional city councils have also entered into the water market, purchasing water entitlements with the aim of drought-proofing urban water supply. As with any other market, traditional investors and speculators are participating in the water market with a view to wealth creation. Similar to financial accounting, which acts as a bedrock of financial markets, water accounting is an integral aspect of the water market. Market participants and observers want to understand the available water resource, by water product, and how that affects the underlying risk profile of water entitlements and allocations. It is also necessary to have rigorous accounts to know the amount of water used and the amount of water remaining against an allocation prior to enacting a trade.

The risk profile of existing entitlement products[7] has been determined by historical patterns of use: in time, place and also return flows. Return flows from upstream irrigators become available for downstream re-regulation. Water traded out of an irrigation district, extracted at a different time of year, or put to a more efficient use (that is, reduced return flows) has an impact on the existing risk profile of water entitlements because less water may be available downstream, or it is available at a different time of year.[8]

The federal government has begun purchasing large volumes of entitlements in order to secure water for environmental purposes. Its purchases of very large water holdings (these may be more than 30 per cent of all extracted water in some valleys) could potentially impact significantly on the underlying risk profile of other entitlements, either positively or negatively. The risk profile of entitlements may also be affected by water reform. For example, the reforms outlined in the *Guide to the Proposed Basin Plan* (realized in 2010) are predicted to increase the security of water available to remaining water holders (MDBA 2010). Water accounting will play an important future role in understanding the risk profiles of entitlements and how those profiles are affected by water trade, change in water use, irrigation efficiencies or government reform.

Water accounting is an important underpinning aspect of all water plans that are required in all catchments under the NWI. It assists planners to understand the water resource available, when and where water is used in the landscape and by whom. This understanding is necessary for planners to determine sustainable extraction limits and to subsequently monitor compliance against those limits. Water accounting can also assist planners to discharge their accountability to the general public and to water users.

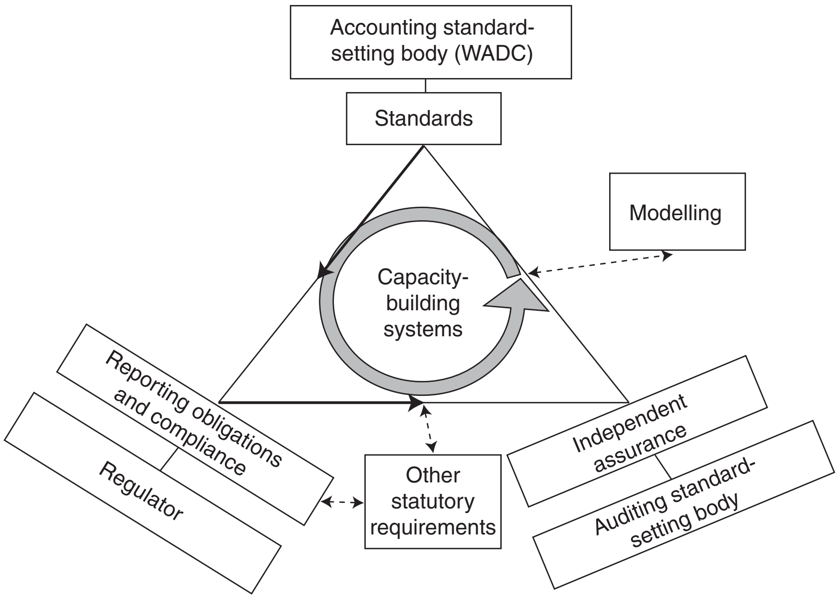
The Living Murray (TLM) programme, begun in 2002, is a joint initiative between the governments of the Commonwealth, New South Wales, Victoria, South Australia and the Australian Capital Territory (MDBMC 2002). TLM is an AUD700 million investment programme, some of which was used to purchase 500 GL of water entitlements from irrigators, to be held and managed on behalf of the environment. At the time of writing, a water sharing plan for the MDB is being prepared. A draft release of that plan proposes that an additional 3000 to 4000 GL of environmental water will be required to maintain MDB sustainability. The Commonwealth government has begun additional buy-back, with a current commitment of AUD3.1 billion.

Buy-back of irrigator water is politically and emotionally charged, creating intense public and investor scrutiny. Governments will be required to discharge their accountability transparently in terms of the water resource to be shared, the amount of water recovered, the subsequent use of recovered environmental water, whether buy-backs have been an effective use of public funds, the outcomes of environmental water delivery and the impacts of buy-back and use of environmental water on water rights of remaining irrigators. Water accounting is necessary to inform all of these questions.

TLM programme includes a series of engineered works and measures along the Murray to deliver water strategically at significant environmental sites with significantly less water than under natural conditions. One scenario is to water multiple sites with the same release as the water passes downstream. It is necessary to ensure that water returning from these sites is not re-regulated for irrigator use. Accountable and transparent return flows calculations will be necessary to ensure the environmental account is not under- or overstated, since these affect the consumptive pool and the risk profile of all entitlements. Governments will also need to discharge their ability in terms of how and when water has been applied to these sites, and what environmental benefits have been achieved. An additional important role of water accounting, since government investments have been made in irrigation efficiency technology, will be to discharge accountability for public funds, water savings delivery and efficiency improvements affecting downstream water rights.

DEVELOPING GENERAL PURPOSE WATER ACCOUNTING

While water accounting has existed for decades in Australia, it has been used primarily for internal agency management purposes, developed and targeted to highly technical insider groups (consisting mostly of engineers and hydrographers). External scrutiny was low and gaps or weaknesses in data sets were not highlighted because they did not need to be; the user group understood the data and their flaws. Similarly, little attention was given to the format of information as the user group understood the data in the absence of an enhanced format. Questions relating to data interpretation could be posed directly to the information preparers. There was no requirement for information to be comparable over time or between organizations. However, in recent years the NWI reforms, particularly market reform and planning, the massive investment by governments in water purchase and water savings and the intense competition for over-allocated resources, all necessitated the development of enhanced water accounting systems. These are needed to provide information to external users who cannot command their own information to enhance decision-making about how water is used, managed and shared and to assist with the discharge of managers' accountability. The system developed in



Source: Chalmers et al. (2009).

Figure 1.2 National water accounting model

response to the NWI is known as General Purpose Water Accounting, which yields General Purpose Water Accounting reports that are intended to inform decision-making by stakeholders who cannot command specific purpose reports for their own use.

The National Water Accounting Development project (NWADp) was established in 2006 to develop water accounting as a discipline in Australia. The NWADp can be explained through the national water accounting model depicted in Figure 1.2. The national water accounting model is a tri-regulatory instrument of (1) standard setting, (2) reporting obligations and compliance and (3) assurance. The model has been designed to meet the objective cited under the NWI of supporting public and investor confidence in the amount of water being traded, extracted for consumptive use and recovered and managed for environmental and other public benefit outcomes.

An independent standard-setting body, initially named the Water Accounting Development Committee and known now as the Water Accounting Standards Board (WASB), is responsible for overseeing and coordinating all Australian Water Accounting Standards (AWAS) development activities. It comprises individuals with expertise in financial accounting, water management and water policy. General Purpose Water Accounting standards are intended to be principles based, rather than rules based, which means they provide a conceptual basis (Schipper 2003) for the preparation of reports. In contrast, rules-based standards prescribe detailed rules that must be followed when preparing statements. Although some rules are unavoidable, the fundamental advantage of principles-based standards is that their broad guidelines can be applied to a variety of situations. Precise requirements under rules-based standards require less professional judgement, but do not necessarily cover all situations.

In a carefully staged programme, a user information requirements study was first undertaken to determine the water-related information that would be useful for potential stakeholders. That study identified the potential for the financial accounting discipline to contribute to the development of a General Purpose Water Accounting system (Slattery 2008). A conceptual framework (The Water Accounting Conceptual Framework for the Preparation and Presentation of General Purpose Water Accounting Reports (WACF)) was then developed to underpin the subsequent development of Australian Water Accounting Standards (WASB 2009). The WACF establishes overarching principles that will be expanded in the water accounting standards and comprises eight Statements of Water Accounting Concepts (SWACs):

1. SWAC1: Definition of the water reporting entity;
2. SWAC2: Objective of General Purpose Water Accounting reports;
3. SWAC3: Qualitative characteristics of General Purpose Water Accounting reports;
4. SWAC4: Definition of elements of General Purpose Water Accounting reports;
5. SWAC5: Recognition of elements of General Purpose Water Accounting reports;
6. SWAC6: Quantification of attributes of General Purpose Water Accounting reports;
7. SWAC7: Compliance disclosures in General Purpose Water Accounting reports; and
8. SWAC8: Assurance of General Purpose Water Accounting reports.

The WACF conceptual framework approved by the WASB underpins an exposure draft, the basis for Australia's first water accounting standard, Exposure Draft of Australian Water Accounting Standard 1, The Preparation and Presentation of General Purpose Water Accounting Reports (ED AWAS 1) (WASB 2010). To support public and investor confidence, publicly available water information is intended to be prepared in accordance with the water accounting standards. These standards are expected to be generally accepted because they will be developed, tested and challenged via an extensive, rigorous and open process that includes formalized steps of initiation, justification, development and testing and implementation, including a cost–benefit analysis.

As the capacity of the water accounting discipline matures, a body of research is likely to develop to test the effectiveness of standards to deliver information that enhances decision-making usefulness. The findings from such research will provide important lessons to future standard setters as standards are reviewed and amended or new standards are developed.

General Purpose Water Accounting in Australia is currently voluntary. However, it is intended that the reporting obligations and compliance component of the national water accounting model will establish which entities will be required to prepare and submit General Purpose Water Accounting reports in accordance with standards, and to whom, according to an institutional framework that has yet to be finalized. It is also intended that implications for non-compliance would be resolved within this framework. The implementation of reporting obligations and compliance will require new institutional arrangements and amendments to existing water legislation. One possible model could be that all water report entities (defined in the ED AWAS 1) are required to have reports produced in accordance with General Purpose Water Accounting standards annually. If so, a regulatory framework for reporting obligations and compliance is important to avoid combat accounting, as described by Lund in Part III Chapter 14. Combat accounting includes the cherry picking of standards and discretion of report preparers over what is the water report entity or who should be accountable for the preparation and presentation of the reports. The multiplicity of levels of institutional responsibilities for water in Australia, federal, state, statutory water corporations and trusts (for example, irrigation trusts), catchment management authorities and corporations (for example, irrigation distribution companies) could create scenarios where an institution could attempt to defer accountability to a higher or lower level of government or institution.

Water accounting can serve two broad functions: to assist management, and to assist external users. Both management and external users can be aided by the discharge of accountability. It is conceivable that in the absence of a framework, stakeholders will continue to produce information in an inconsistent and ad hoc fashion (Sinclair Knight Merz 2006; National Water Commission 2010). A regulatory framework will ensure that, to the extent enforceable, all water report entities discharge their accountability in a comparable way, with a consistent objective and qualitative characteristics, in accordance with a rigorous theoretical framework.

The third aspect of the national water accounting model relates to the assurance of General Purpose Water Accounting reports. The WASB is currently working with Australia's national Auditing and Assurance Standards Board to produce an auditing and assurance standard that will prescribe general principles regarding who can conduct different types of water accounting audits (for example, the audit of a physical entity such as a river system is likely to require very different skills from the audit of an organization that trades water rights but does not actually use or manage water), the nature of the assurance they can provide and the principles underpinning the practice of audit and assurance of General Purpose Water Accounting reports.

CONCLUSION

This chapter has explored the background and context of water sharing and the evolution of General Purpose Water Accounting. It outlines the types of decisions that can be supported or enabled by water accounting and describes the development of General Purpose Water Accounting in Australia. The hydrographers' legacy over a century of water accounting has created an opportunity for accountants to further apply their discipline to this vital natural resource. This situation enables the marrying of two disciplines: the mature hydrographers' discipline, bringing expertise in measuring, modelling and recording water, combined with a mature financial accounting and reporting discipline underpinned by an extensive body of evidence and a conceptual approach to reporting information to enhance decision-making.

The challenges facing Australia as it develops its system of General Purpose Water Accounting are increasing the level of voluntary adoption of the system (or establishing a regulatory regime that makes it mandatory) and developing additional standards to enhance the decision usefulness of reporting. The latter could include standards to cover audit and assurance of General Purpose Water Accounting reports (it may be advisable to develop separate standards for physical and organizational water report entities), water accounting for joint ventures between water report entities, consolidation of multiple entities' reports, accounting and auditing environmental water, disclosure of modelled information, disclosures relating to sustainable diversion limits, and accounting for differences in water quality.

Research is currently in progress to assess the benefits and costs of General Purpose Water Accounting and how those benefits and costs are distributed amongst different stakeholders. It will be interesting to see how this research, and the related politics, influence future directions in the water accounting standard setting arena. It will also be interesting to see whether and how the advent and adoption of General Purpose Water Accounting affects gauging and other methods of metering or modelling water volumes and quality in order to report greater precision and reliability. It is likely, as in other industries, that new reporting will lead to the development of tools to support that reporting and to improve the faithfulness of its representations to external users.

At present there is growing interest, both nationally and internationally, in water accounting in Australia. If this interest transforms into large-scale adoption, it will provide attendant benefits for General Purpose Water Accounting reports users who will be able to compare reports over time and across entities in order to make decisions ranging from economic (for example, whether to invest in a corporation subject to water supply risk, whether to lend to a state or water authority, how to price water), social and cultural (for example, whether to retain a community recreational lake, whether to stop supply to areas of cultural sensitivity), environmental (for example, whether to increase environmental flows with implications for water allocations), to political (for example, whether to vote for a government according to its water policies). For these benefits to eventuate, Australia will need to move quickly to establish a regulatory framework for requiring and enforcing General Purpose Water Accounting and to build capacity through training and research that will contribute to the quality and entrenchment of the system. While General Purpose Water Accounting reports will not prevent any droughts of the nature that Australia has experienced in the past, they may nonetheless provide information that underpins the decisions that reduce risk arising from poor information and poor decisions, and even possibly prevent or mitigate water crises in the future.

NOTES

1. See: Department of the Environment, Water, Heritage and the Arts (2008), http://www.environment.gov.au/water/publications/mdb/pubs/mdb-map.pdf; accessed 1 October 2011.
2. See: Natural Resources and Mines (2004), http://www.longpaddock.qld.gov.au/products/australiasvariableclimate/index.html; accessed 1 October 2011.
3. This phrase is included in 'Advance Australia Fair', the national anthem of Australia.
4. The Great Dividing Range is the mountain range spanning in excess of 3500 km from Northeast Queensland through New South Wales and then into Victoria.
5. See: Department of Sustainability, Environment, Water, Population and Communities

(2007), http://www.environment.gov.au/water/publications/mdb/dry-inflow-planning.html; accessed 1 October 2011.

6. For example, subsequent to the NWI agreement, significant efforts and investment have been made to ensure diversion points are metered and metering accuracy is improved. Dethridge wheels are being phased out and a metering standard applies of +/− 5 per cent on new meters nationally, which will apply to all water entitlements. The coverage of a critical mass of accurate metering enables water accounting to be implemented.
7. Entitlement products are entitlements to access a share or volume of water from a source. They differ between and within states. Generally, each state's entitlement products include high- and low-reliability products.
8. There is a limit on farm storage along the River Murray.

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2. The System of Environmental-Economic Accounting for Water: development, implementation and use

Michael Vardon, Ricardo Martinez-Lagunes, Hong Gan and Michael Nagy

INTRODUCTION AND BACKGROUND

The System of Environmental-Economic Accounting for Water (SEEAW: United Nations Statistics Division 2007) is a conceptual framework for organizing economic and environmental data related to water. It describes key hydrological and economic concepts and defines a set of standard tables for presenting hydrological and economic information, which show the interaction between water and the economy as well as water resources in the environment. The SEEAW provides a direct link from hydrological data to the System of National Accounts (SNA), the framework used in macroeconomic statistics throughout the world for more than 50 years and from which the accounting identity gross domestic product (GDP) is derived.[1]

The SEEAW was developed between 2004 and 2007 by the United Nations (UN) Statistics Division with the assistance of several countries and a range of international organizations. It consolidates the experiences and practices of countries and international organizations in the field of water accounts. The UN Statistical Commission adopted the SEEAW as an interim international statistical standard at its 38th Session in March 2007.[2] The SEEAW is an elaboration of the handbook *Integrated Environmental and Economic Accounting 2003* (United Nations et al. 2003), commonly referred to as SEEA-2003, which describes the interaction between the economy and the environment and covers the whole spectrum of natural resources and the environment.

The SEEAW was adopted as an interim standard pending the elevation of the overarching framework for environmental accounting, the SEEA, to an international statistical standard, which is expected in 2012. At the time SEEAW was adopted it was recognized that it provided a much needed conceptual framework for organizing hydrological and economic information in support of integrated water resource management (IWRM).[3] Since adoption in 2007 other fora have also recognized the potential usefulness of the SEEAW.[4] A key document developed explicitly to support the SEEAW as well as for harmonizing international data collection activity related to water is the 'International Recommendations for Water Statistics' (IRWS) (UN Statistics Division 2010). The IRWS was adopted by the UN Statistical Commission in February 2010[5] and it provides more detail and guidance on the basic statistical data (covering hydrological, economic and social data) needed to populate the SEEAW standard tables.

This chapter provides an overview of the SEEAW, including the main concepts and features of the systems, some examples of implementation in countries and some of the challenges in the implementation of the system. However, before describing these aspects of the SEEAW it is useful to present a short section on audiences for information.

AUDIENCES FOR INFORMATION

A key consideration when designing a system for the production of information is the different audiences for which information is produced. In general only limited information is used by senior decision-makers and the general population, whereas policy analysis and researchers use greater levels of detail. This can be represented by an information pyramid, with the more detailed information at the bottom and indicators at the top and accounts in the middle layer (Figure 2.1). The accounts draw the data from a wide range of sources (the base of the pyramid) and smooth them into a consistent information source that is suitable for analysis and for the construction of indicators.

The information pyramid has a counterpart in the audience pyramid, with the number of users of the different layers of information in inverse proportion to the level of detail. In this it should be noted that the accounts and the indicators are only as good as the basic data. The layers do not preclude contact between the various agents and in particular researchers, managers and analysts all provide advice to decision-makers or provide information and commentary to the wider public.

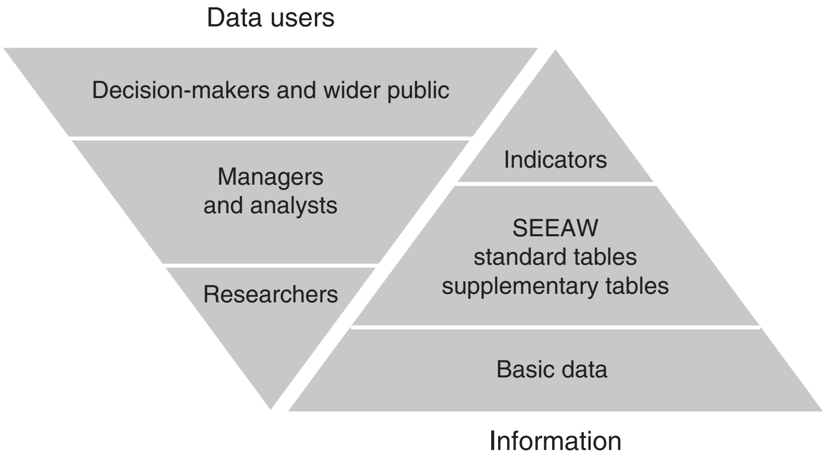


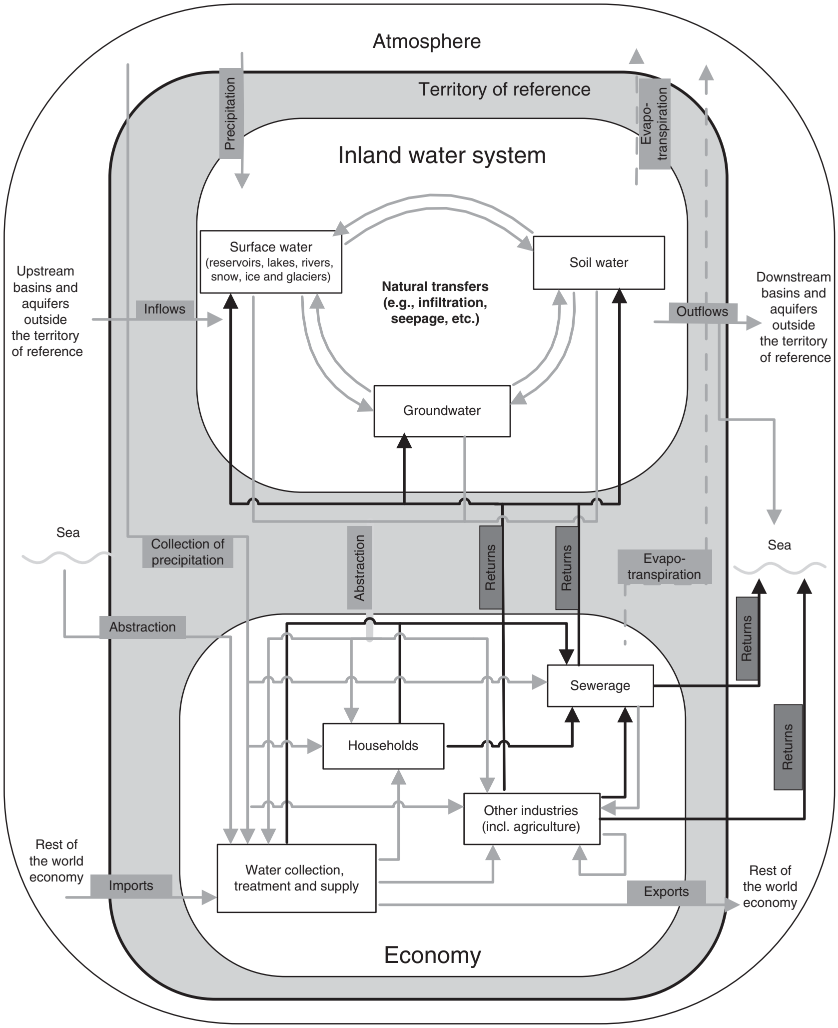
Figure 2.1 The information and audience pyramids

MAIN FEATURES OF THE SEEAW

A conceptual overview of the scope of SEEAW is presented in Figure 2.2. This figure is a simplified presentation of the physical flows of water within the inland water resources system (or the environment) and the economy represented in the figure as two separate boxes. Many of the flows, and in particular those within the economy, have matching monetary flows. A territory of reference may be a country, river basin or other type of spatial boundary. The SEEAW also covers the discharge of pollutants and water quality.

The inland water resource system of a territory is composed of all water resources in the territory (surfacewater, groundwater and soil water) and the natural flows between them. The economy of a territory consists of resident water users who: extract water for production and consumption purposes; put in place the infrastructure to store, treat, distribute and discharge water; and discharge water back to the environment.

The SEEAW defines a series of accounting identities to allow consistent comparisons between areas and over time. This is necessary because some terms, such as water use and water consumption, mean different things in different data systems. By identifying these as a sum of particular data items, countries and international organizations are able to understand how their particular definitions relate to those in the SEEAW and over time these should harmonize with the SEEAW.



Source: System of Environmental Economic Accounting for Water (Final Draft) (UN Statistics Division 2007).

Figure 2.2 Scope of SEEWA: main flows within the inland water system and the economy

Stocks (Assets)

Stocks are the quantity of a particular product or natural resource at a point in time. Stocks are identified in both economic and environment statistics, although the terminology varies depending on the context, and they can be measured in physical and monetary terms. Physical stocks of water may also have different levels of water quality. Assets are usually associated with stocks that have economic values and in the SNA stocks are recorded in balance sheets in monetary terms for non-financial assets (produced and non-produced), financial assets and liabilities. In the SEEAW stocks are recorded in the asset accounts in physical terms (the volume of water).

Stocks are measured at a point in time, often the end of a year. The stocks at the beginning of a time period are called the opening stocks and those at the end of the period (start time plus one year) are called closing stocks. The difference between opening and closing stocks is the result of flows (additions and subtractions) to the stocks. For the SEEAW, stocks are typically measured annually on 31 December. Water stocks (or assets) are classified by the SEEAW as surfacewater, groundwater and soil water. Surfacewater is further disaggregated and includes artificial reservoirs, lakes, rivers, snow, ice and glaciers. Changes in water stocks are due to flows of water within the environment (for example, between surfacewater and groundwater) or flows between the economy and the environment. Changes in stocks can also result from increased knowledge regarding stocks (for example, the discovery of new aquifers or the reassessment of already identified inland water resources).

Flows

Flows are the quantity that is added or subtracted from a stock during a specific period of time. Flows are identified in both economic and environment statistics. Economic flows reflect the creation, transformation, exchange, transfer or extinction of economic value; they involve changes in the volume, composition, or value of an economic unit's assets and liabilities.

In water statistics flows are measured as a quantity (volume, mass, or value) per unit of time: for example, m^3 per year, tonnes per year or dollars per year. The flows are usually related to particular stocks of water and flows result in a change in quantity of the stocks. The flows described in water statistics are (1) flows within the environment (between inland water resources and the atmosphere, between the sea and inland water resources as well as the flows between the different inland water resources such as surfacewater, groundwater and soil water); (2) flows from the environment to the economy (abstraction); (3) flows within the economy (exchanges of water between economic units); (4) flows from the economy to the environment (returns and waterborne emissions); and (5) flows with other territories (inflows and outflows with neighbouring territories). It is not always possible to establish a simple physical boundary between the economy and the environment. Despite this, it is still necessary to look at the type of flows of interest within the economy, the flows into and out of the economy and the flows within the environment.[6]

Water Consumption and Water Use

The definition of water use and water consumption varies between information systems. In the SEEAW the definition of water use includes the use of water for hydroelectric power generation and the use of water for cooling in industrial processes. These types of water use are separately identified in the SEEAW tables as, while the use may be large, the water is not consumed and is usually available to other users. That is, the water may be supplied to other users in the economy or returned to the environment, with little if any change to the physical characteristics of the water (apart from being displaced in time and space and with the addition of heat in the case of cooling water).

SEEAW defines consumption as being total use minus total supply (supply to both other economic units and to the environment, also known as return flows). This provides an indication of the amount of water that is lost by the economy during use in the sense that it has entered the economy but has not returned either to water resources or to the sea. This happens because during use part of the water is incorporated into products, evaporated and transpired by plants. Water consumption can be computed for each economic unit, for industries and for the whole economy. The concept of water consumption used in the SEEAW is consistent with that used in water management. However, it differs from the concept of consumption used in the SNA, which instead is more akin with the SEEAW definition of water use.[7]

Spatial References for Water Accounts

Information for water management is required at many geographic levels, from the local, to the river basin, to the national and multinational levels. The choice of the spatial reference for the compilation of water accounts ultimately depends on the data needed by users (for example, decision-makers, analysts and researchers) and the resources available to data producers. The SEEAW recommends the river basin as the spatial unit for which the accounts should be compiled.

In general, four types of spatial boundaries are used in water statistics: (1) physical boundaries (for example, river basins and other surfacewater boundaries, such as sub-basins, drainage basins, water catchments; aquifers and other sub-surface boundaries including aquifer beds, complex aquifer-aquitard systems, groundwater provinces, groundwater regions); (2) administrative regions (for example, local, state/provincial and national governments); (3) service areas; and (4) accounting catchments.

Physical boundaries in the form of river basins or aquifers are fundamental to the hydrological cycle. These physical boundaries can span large areas, national administrative boundaries and countries. Aquifers are below-ground reservoirs of water, while a river basin is an area having a common outlet for its surface runoff.[8] River basins vary in size depending on the common water body of interest and large river basins may contain smaller sub-basins (or catchments). River basins are fundamental to understanding surfacewater resources as the water suppliers and users within a river basin directly affect the availability of water. In addition, water can flow naturally between river basins or can be imported and exported by economic units located in different river basins, but within the one country.

It is internationally recognized that a river basin is the most appropriate spatial reference for IWRM (for example, World Water Assessment Programme 2009 and the European Water Framework Directive (European Commission 2000)). This is because the people and economic activities within a river basin will have an impact on the quantity and quality of water in the basin, and conversely the water available in a basin will affect the people and economic activities that rely on this water. As such, river basins are suggested for the compilation of water statistics.[9] However, in areas where groundwater is an important source of water, aquifers may also be appropriate for the compilation of water statistics.

An administrative region is a geographic area usually corresponding to a level of government (for example, local, state/provincial or national). Administrative regions are usually responsible for planning and economic policies within their jurisdiction and, as such, different regions are likely to have different laws, regulations, institutional arrangements and management practices relating to water.

Water suppliers or sewerage service providers, which may be government or non-government, will often have service areas that are related to the physical infrastructure, which they own or operate to supply water or sewerage services. For example, a particular water supplier may supply water to more than one city or town and these may be in two different river basins or administrative areas (for example, local government areas).

Accounting catchments are defined in the SEEAW because, depending on the characteristics of the administrative regions and river basins in a country, especially where there is a mismatch of boundaries, it may be useful to define regions for the compilation of water statistics and accounts for which both economic and physical data are more easily available. As such, these regions are statistical constructs or hybrids of administrative regions and river basins. Accounting catchments are used to provide the best possible match of economic, environmental and social data, which use a variety of spatial references. They are usually large enough so that economic information is available.[10]

In practice, an accounting catchment is usually an administrative region, composed of all or parts of several river basins or a river basin composed of all or parts of several administrative regions.[11] Usually whole administrative regions are added together to form the nearest approximation of a river basin or vice versa.[12] In defining accounting catchments, it is necessary to compare river basins and administrative boundaries to determine the best possible match based on practical considerations of data availability and data collection. Over time the use of accounting catchments should lead to improvements in data collection and availability.

Each administrative region, river basin, service area or accounting catchment used for water statistics should have a unique identification code and name. If more than one spatial reference is used, there should be more than one identification coding system and the codes used should be distinct. When the relevant boundaries are available electronically, geographic information systems can help clarify boundary issues related to water statistics.

Temporal (Time) References

It is important when integrating or collecting water data that the reference periods for the water data align. In water and economic statistics the calendar year is the recommended temporal reference. However, in practice, water and economic data may not be available for calendar years. For example, for national accounts many countries use a financial year, while for water statistics countries may use a hydrological year. A hydrological year is a 12-month period such that the overall changes in storage are minimal and carryover is reduced to a minimum.[13] Financial and hydrological years may be the same as or different from calendar years.

It is generally recommended that water accounts are developed for the time period used in the national accounts, which in the SNA is recommended to be the calendar year. This allows direct temporal comparability between economic and environmental aspects of water statistics. Yearly water statistics will often hide seasonal variability in data that, in many cases are important to understand for water management purposes. Some water statistics, like precipitation and other meteorological and hydrological data, are compiled more frequently (for example, daily, weekly or monthly) to address these needs.

IMPLEMENTATION AND USE OF THE SEEAW

In order to assess the use and implementation of the SEEAW (and other issues related to the compilation of water statistics) around the world, the UN Statistics Division undertook the Global Assessment of Water Statistics and Accounts in 2008. Only brief summary results are reported here but they were reported in full to the UN Statistical Commission in 2009.[14]

At the time of the Global Assessment (2008), 44 countries had implemented, or planned to implement, water accounting. Of these, 33 were compiling some form of water accounts, while 11 countries indicated that they would begin to compile water accounts in the next two years. Since the Global Assessment an additional four countries have begun compiling environmental accounts, bringing the total number of countries currently compiling or planning to compile accounts to 48. The number of countries producing water accounts or implementing the SEEAW increased significantly from 22 in 2006 to 48 in 2008 (UN Statistical Commission 2009).

The level of implementation varies greatly between countries and the number of countries regularly producing water accounts is small. Many countries of the European Union have regular accounts for water emissions and environment protection expenditure relating to water, while leading implementers of the physical supply and use tables include Australia, the Netherlands and Spain. China and Mexico are making rapid progress with a range of water accounts. The most commonly compiled accounts in countries were the physical supply and use tables (prepared in 21 countries), economic accounts (17 countries), asset accounts (12 countries) and emission accounts (ten countries). The order of importance of the accounts compiled varies by region and level of economic development, but in both developed and developing regions the physical supply and use tables and the economic accounts were the two most commonly produced types of accounts. Emission accounts were more important in developed regions compared to developing regions, while the reverse was true for asset accounts.

The institutions that compile water accounts vary from country to country (ibid.). In 17 of the 33 countries that currently compile water accounts, the national statistical offices perform the compilation. In six countries the statistical offices and other agencies both compile water accounts. In ten countries agencies other than statistical offices compile the water accounts. The spatial level at which the water accounts are produced varies between countries. In 28 countries water accounts are produced at national level, while ten countries also produce water accounts at the administrative regional level. Water accounts were used for policy-making (14 countries), IWRM (11 countries), reporting to international agencies (ten countries) and research and modelling (ten countries) (ibid.). Water accounts are used as input to the development of national water policies, water pricing, water resources allocation, improving water use efficiency, budgeting and designing of water projects, predicting future demands for water, input–output analyses, predicting implications of water reforms for the national economy, flood forecasting and modelling for climate change scenarios. Indicators derived from water accounts are used for sustainable development, water resource and use and water quality. The main users of water accounts are the Ministries of Environment (18 countries), academics (15 countries), Ministries of Agriculture (seven countries) and industry groups (six countries).

COUNTRY EXPERIENCES

Below we briefly present three examples of how SEEAW is being implemented in countries with which we are most familiar: Australia, Austria and Mexico. In addition, the implementation of SEEAW in China is addressed in Chapter 8, while Lange and Hassan (2006) address water accounting in southern Africa.

Australia

While water accounts are a relatively new development in Australia, Australia has a long history of producing information on water resources and water use in the Australian economy (Australian Water Resources Commission (AWRC) 1965, 1977, 1987; Department of Natural Development and Energy 1981; Australian Academy of Technological Sciences and Engineering 1999; National Land and Water Resources Audit 2001; National Water Commission 2007; see Vardon et al. 2007 for a summary). The compilation of annual water accounts in Australia was identified as a priority in the National Water Initiative and subsequently identified in the Water Act 2007.

National-level water accounting in Australia is currently practised by the Australian Bureau of Statistics (ABS) and is being developed by the Bureau of Meteorology (BoM). The ABS has so far produced four editions of the Water Account, Australia (ABS 2000, 2004, 2006 and 2010), with the next edition due in November 2011. The data presented in the ABS is for the country as a whole as well as for each of the eight states and territories. The ABS has also prepared water accounts for the Murray Darling Basin.[15] The BoM has so far produced a pilot national account for several regions of Australia (BoM 2010), with additional regions to be added over time.

The water accounts produced by the ABS and BoM are very similar in form to the standard tables of the SEEAW. The ABS water accounts are like the physical and monetary supply and use tables, while those of the BoM are like the asset account. Data from the 2004–05 ABS water account has been placed in the SEEAW standard physical supply and use table (see Table 2.1), while the data from the BoM pilot account has been placed in the asset account (see Table 2.2). These tables are not the official work of either the ABS or BoM but are the authors' interpretation of the data from these organizations and how they fit into the SEEAW framework.

The SEEAW asset account and the BoM account align almost exactly, with some presentational differences and the main substantive difference being that the BoM account includes additional information on past and future administrative commitments to water supply.

The SEEAW physical supply and use tables and the ABS account also match up. Again there are some presentational differences, with the ABS showing industries in the rows rather than columns as well as having more detailed industry information. The main substantive differences are that the ABS account does not record the use of soil water or the supply of wastewater to the sewerage industry and has a different definition of water consumption. The ABS definition of consumption differs mainly due to a lack of data on return flows and of the flows of wastewater from industries and households to the sewerage industry. While some returns to the environment (called regulated discharge) are shown for some industries in the ABS account, they are not shown for all industries and non-point discharges (for example, runoff from agricultural land) are not recorded at all. As such the SEEAW consumption identity cannot be calculated consistently for all industries at this time in Australia and for the time being the ABS will continue to use an alternative definition until the required data are available.

Table 2.1 ABS physical supply and use table for 2004–05 in SEEAW format

Use Table		Industries (by ISIC Categories)							Households	World	Total
		1–3	5–33, 41–43	35	36	37	38, 39, 45–99	Total			
From the environment	1. Total abstraction (=1.a+1.b =1.i+1.ii)	6977	775	60172	11160	0	467	79551	232		79783
	1.a Abstraction for own use	6977	775	60172		0	467	68391	232		68623
	1.b Abstraction for distribution				11160			11160			11160
	1.i From water resources:							0			0
	1.i.1 Surface water				10712			0			0
	1.i.2 Groundwater				448			0			0
	1.i.3 Soil water[a]							0			0
	1.ii From other sources							0			0
	1.ii.1 Collection of precipitation							0			0
	1.ii.2 Abstraction from the sea (desalination)				<1			0			0
Within the economy	2. Use of water received from other economic units	5609	474	121	39	2234	122	8599	1876		10475
	3. Total use of water (=1+2)	12586	1249	60293	11199	2234	589	88150	2108	0	90258

Table 2.1 (continued)

Supply table		Industries (by ISIC Categories)							House-holds	World	Total
		1–3	5–33, 41–43	35	36	37	38, 39, 45–99	Total			
Within the economy	4. Supply of water to other economic units		25	162	5942	425		6554			6554
	of which:										0
	4.a Reused water		2	7		425		434			434
	4.b Wastewater to sewerage	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		2234
To the environment	5. Total returns (= 5.a+5.b)	0	721	59924	47	1809	0	62501	0		62501
	5.a To water resources	0	721	59924	47	1809	0	62501	0		62501
	5.a.1 Surface water			59924		553					0
	5.a.2 Groundwater					23					0
	5.a.3 Soil water[a]										0
	5.b To other sources (for example sea water)					1231					0
	6. Total supply of water (= 4+5)	0	746	60086	5989	2234	0	69055	0	0	69055
	7. Consumption (3–6)	12586	503	207	5210	0	589	19095	2108	0	21203

Note: a. Soil water not included in ABS water accounts to date; n.a = not available.

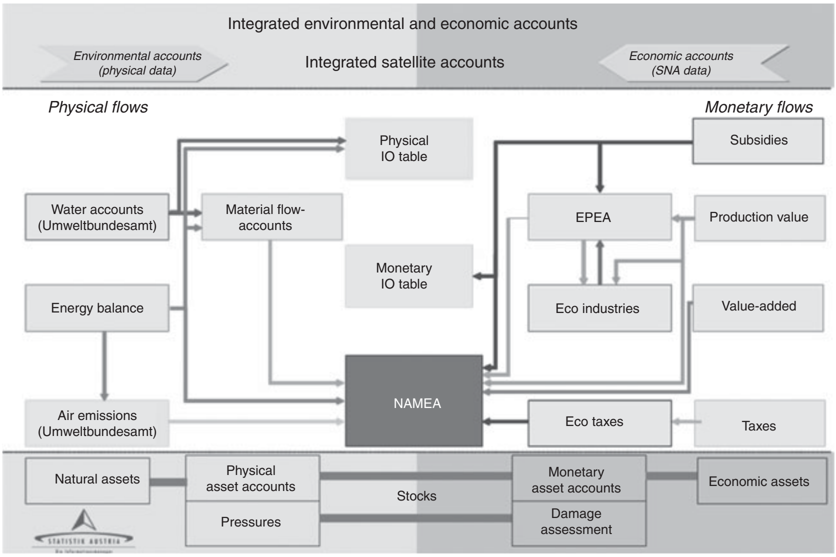
Table 2.2 BoM face statement for Namoi-Peel catchment in SEEAW asset account format: 2007–08

Namoi-Peel (Megalitres)	EA.131 Surface Water				EA.132 Ground-water	EA.133 Soil Water	Total
	EA.1311 Artificial reservoirs	EA.1312 Lakes	EA.1313 Rivers	EA.1314 Snow, ice and glaciers			
1. Opening stocks – 2007	125 936		3114		7 530 612	6 984 154	14 643 816
Increases in stocks	669 710	0	0	0	76 860	28 378 940	29 125 510
2. Returns							0
3. Precipitation	668 017					28 378 940	29 046 957
4. Inflows							0
4.a. From upstream territories					15 282		15 282
4.b. From other resources in the territory	1693				61 578		63 271

Table 2.2 (continued)

Namoi-Peel (Megalitres)	EA.131 Surface Water				EA.132 Ground-water	EA.133 Soil Water	Total
	EA.1311 Artificial reservoirs	EA.1312 Lakes	EA.1313 Rivers	EA.1314 Snow, ice and glaciers			
Decreases in stocks	521 882	0	83 549	0	74 253	25 010 546	25 690 230
5. Abstraction	60 594				60 656		121 250
6. Evaporation/Actual evapotranspiration	440 380					24 969 876	25 410 256
7. Outflows							0
7.a. To downstream territories					13 597		13 597
7.b. To the sea							0
7.c. To other resources in the territory	20 908		83 549			40 670	145 127
8. Other changes in volume	−32 560		82 192		0	−3 359 812	−3 310 180
9. Closing stocks – 2008	241 204		1757		7 533 219	6 992 736	14 768 916

Note: Grey cells indicate non-relevant or zero entries by definition in the SEEAW.



Note: Water accounts in Austria are in a development phase; EPEA = Environment Protection Expenditure Accounts; NAMEA = National Accounting Matrix with Environmental Accounts.

Source: *Statistics Austria.*

Figure 2.3 The System of Environmental-Economic Accounts in Austria

Austria

Austria has many years of experience in the practical implementation of environmental economic accounts. Since 1995, Statistics Austria has regularly produced accounts for material flows, air emissions, energy and environmental protection expenditure. In doing so, Statistics Austria has cooperated with other institutions such as the Austrian Environment Agency (Umweltbundesamt). Figure 2.3 is an overview of the system of environmental economic accounts in Austria.

While the production of regular water accounts has not been possible to date, there is a desire to add water accounts to those regularly produced as part of the Austrian environmental-economic accounting system. The lack of resources for water accounting is partly explained by the absence of European Union legislation or regulation. Unlike material flow accounts, air emissions accounts and environmental taxes where a draft European regulation exists, a regulation for water accounts is yet to be developed.

Despite the lack of a legal imperative, and therefore resources, to produce water accounts the Austrian Environment Agency and Statistics Austria have initiated several pilot studies (partly financed by Eurostat). These studies have produced pilot accounts and also provided valuable experience in water accounting that will assist in regular production of water accounts in the future.

Work on water accounting in Austria began in 1998 with the pilot implementation of water emission accounts (Fürhacker et al. 1999). The chosen approach was that of Eurostat, which is conceptually identical with the wastewater emission tables of SEEAW, although there are some presentational differences. The study showed the approximate share of major pollutants emitted by different industries in the economy and also highlighted problems in data quality and data collection. Most of the shortcomings in data were solved with the advent of the European Water Framework Directive (2000/60/EC). This directive required European Member States to establish registers for the most important sources of emissions, both point and diffuse sources. The data from this register allow for the regular production of wastewater emission accounts in Austria.

The main results of the pilot study on water emission accounts are presented in a so-called 'butterfly matrix' with economic indicators (industry value-added, production value and number of employees) by industry (as classified by NACE, which is equivalent to ISIC[16]) and water pollution parameters (COD, BOD5, TOC, nitrogen, ammonia, phosphorus, AOX, heavy metals) and wastewater volumes (Nagy 2009). A second pilot study is examining the physical supply and use tables for water and how they may be produced regularly. However, for the time being, a lack of resources means that water accounts in Austria can only be produced on an ad hoc basis.

Mexico

The National Water Commission of Mexico (CONAGUA) has developed the National Water Information System (SINA), which is defined in the National Water Law as a basic tool for water policy design and evaluation. The SINA is based on the information related to water that is produced by the different areas of CONAGUA and other government agencies in Mexico. A partnership between the different data producers is essential for the SINA, and in particular the partnership between CONAGUA and the national statistics office of Mexico (INEGI). The SEEAW and the IRWS have provided the framework for organizing the information in SINA.

Preliminary physical use and supply tables have been prepared for Mexico for 2006 (Table 2.3). The tables are based on the SEEAW standard tables, but the industry breakdown has been simplified and soil water

Table 2.3 Preliminary Mexico SEEAW physical supply and use tables 2006

(a) Physical use table

		ISIC Classification						Households	Total
		1–3	3, 38–99	35		36	37		
		Agriculture, livestock and aquaculture	Industry and services	Thermo-electricity	Hydro-electricity	Public water supply	Sewerage		
From the environment	1. Total abstractions	59 400	2 971	4 209	140 295	10 665	2 589	38	220 168
	1.a Abstractions for own use	59 400	2 971	4 209	140 295			38	206 914
	1.b Abstraction for distribution					10 665			10 665
	1.i From water resources	59 400	2 971	4 209	140 295	10 665		38	217 579
	1.i.1 Surface water	39 720	1 606	3 751	140 295	3 877		14	189 262
	1.i.2 Groundwater	19 680	1 366	458		6 788		25	28 317
	1.i.i. From other sources						2 589		2 589
	1.i.i.1 Stormwater						2 589		2 589
Within the economy	2. Use of water received from other economic units	4 124	1 488	62	0	0	3 902	4 290	13 866
	3. Total water use (=1+2)	63 524	4 459	4 272	140 295	10 665	6 491	4 328	234 034

Table 2.3 (continued)

(b) Physical supply table

		ISIC Classification						House-holds	Total
		1–3	3, 38–99	35		36	37		
		Agriculture, livestock and aquaculture	Industry and services	Thermo-electricity	Hydro-electricity	Public water supply	Sewerage		
Within the economy	4. Supply of water to other economic units, of which:	0	1797	0	0	5228	3379	3463	13866
	4.a Reused water		1357				3379		4737
	4.b Wastewater to sewerage		439					3463	3902
To the environment	5. Total returns	36317	2139	4058	140295	5438	3112	187	191546
	Losses	21559				5438			26996
	Treated wastewater		874				2346		3220
	Untreated wastewater	14758	1266	4058			765		20847
	6. Total supply of water (=4+5)	36317	3936	4058	140295	10665	6491	3650	205412
	7. Consumption (=3−6)	27207	523	214	0	0	0	678	28622

Source: CONA Gun and INEGI.

is omitted. The tables were prepared jointly by CONAGUA and INEGI. The tables show all the flows of water within the economy and this information can now be combined with information on economic output, production and use to generate SEEAW hybrid tables, which in turn can be used to derive economic indicators such as water productivity.

The data used to produce the physical supply and use tables came from a range of sources and the tables are being prepared for the years 2001 through 2008 to identify trends over this time. The construction of the tables helped to identify specific data gaps and data deficiencies and this was then used to design a data collection strategy to improve the quality of future accounts. A similar approach to identifying data gaps and data deficiencies is being used in the preparation of the other SEEAW standard tables (for example, the asset account and hybrid account).

In addition to national physical supply and use tables, tables are also being prepared for specific regions of the country, such as the Lake Chapala region, a highly water-stressed area of the country. The production of subnational accounts is particularly important for Mexico given the widely varying climate (that is, very dry in the north and very wet in the south) and the location of various activities (some parts of Mexico, such as the area around Mexico City, are more industrialized than others).

CHALLENGES WITH THE IMPLEMENTATION OF THE SEEAW

The Global Assessment (UN Statistical Commission 2009) identified the factors impeding the compilation of water accounts (Table 2.4). The two most common impeding factors were data availability (74 per cent) and data quality (55 per cent). The availability and quality of the data used to populate the accounting tables is a fundamental concern. While countries will often have some of the data needed for the accounts, no country has access to all of the data needed to produce the full suite of accounts. As such the countries producing accounts rely on a range of estimation methods to populate particular cells in the tables produced. In some cases data may exist but the agency or agencies producing the accounts may not be able to access the data for legal, administrative or technical reasons.

There were differences in the factor identified between developed and developing regions. For example, the countries from developing regions identified the lack of compilation guidance material (50 per cent) as a significant impeding factor, while data availability (81 per cent) and data quality (63 per cent) were more significant concerns in developing regions than in developed regions.

Table 2.4 Factors impeding the compilation of water accounts

Water Accounts	All Regions		Developed Regions		Developing Regions	
	Number of countries	Percentage of countries	Number of countries	Percentage of countries	Number of countries	Percentage of countries
Total countries responding to question	31	100	15	100	16	100
Lack of cooperation/ data sharing with other institutions	10	32	4	27	6	38
Lack of compilation guidance material	11	35	3	20	8	50
Lack of harmonized measurement units within the country	7	23	3	20	4	25
Lack of internationally agreed methodology	6	19	3	20	3	19
Lack of harmonized classifications	4	13	1	7	3	19
Data availability	23	74	10	67	13	81
Data quality	17	55	7	47	10	63
Lack of interest from users	10	32	3	20	7	44
Confidentiality	6	19	2	13	4	25

Source: UN Statistical Commission (2009).

One of the main challenges in the production of water accounts is the large number of agencies and the diverse range of professional disciplines (for example, physical water scientists, economists, engineers, statisticians, and so on) that are involved in their production. This makes the legal and institutional frameworks, coordination and cooperation among different agencies a key for the success and sustainability of the water data collection and water accounting programmes in countries.

Legal frameworks or other instruments related to water management and statistics exist in most countries and cooperation between agencies in the production of water data and water accounts occurs in most countries. However, the Global Assessment identified a lack of cooperation or data sharing as an issue in 32 per cent of countries preparing water accounts.

CONCLUSION

The SEEAW has been developed and implemented in countries in a relatively short space of time. The growing number of countries producing water accounts may be attributed to several factors. These include the pressing need for integrated environmental and economic information, the adoption on the SEEAW as an interim international statistical standard by the UN Statistical Commission in 2007[17] and the subsequent SEEAW implementation plan carried out by the UN Statistics Division. The latter involved regional training workshops, in-country technical assistance and cooperation with existing regional programmes on water statistics and accounting. This has had a positive impact on the implementation and strengthening of the water statistics and accounts programmes in many countries, but particularly in Latin America and the Middle East.

Continued growth in the implementation of SEEAW can be expected when international agencies, and especially UN agencies, Organisation for Economic Co-operation and Development (OECD) and Eurostat, begin to use the SEEAW for the collection, compilation and dissemination of water statistics. In addition, with the completion of the IRWS,[18] countries will have access to more of the information needed to compile the accounts.

The national statistical offices of countries have played a key role in many, but not all, of the countries implementing water accounts. From the Global Assessment and through the experience of assisting countries with the implementation of SEEAW and the development of the IRWS, it is clear that the statistical offices are important players for a number of reasons: (1) they usually have a legal mandate, organizational structure and capacity to regularly collect and disseminate data; (2) they often collect data on water abstraction, treatment and distribution through household and business surveys; (3) they are usually the source of the national accounts data, which are essential to the production of many of the SEEAW standard accounting tables, and especially the tables from which the economic indicators are derived; (4) they often have experience in bringing together various stakeholders and help to ensure the commitment to the development and implementation of a multipurpose integrated information system (the SEEAW) in countries, to meet the wide variety of users' needs; and (5) they have experience in harmonizing definitions, developing and implementing standard classifications and ensuring their harmonization with those used in economic and social statistics.

The role of the water, hydrological and meteorological department agencies is also important as they are usually the agencies that collect the data on the physical water resources. They too have expertise in implementing standards, harmonizing definitions and developing systems for the regular production of data. Ultimately the statistical and water agencies of countries need to work together in order to produce a fully integrated system of water accounts covering both the economic and environmental aspects of water use. Social concerns are not yet fully integrated but the SEEAW provides a framework into which they can be added and the first steps of this were taken with the development of the IRWS. Further growth in the use of water accounts can be expected as the compilers of accounts gain more experience with the theoretical framework and practical aspects of producing the accounts and as water managers and policy developers become familiar with the structure of the accounts and how they can be used in analyses at the regional and country levels.

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The views in this chapter represent those of the authors and do not necessarily represent the view of the organizations that employ them.

NOTES

1. The SEEAW is part of a family of UN statistical standards. The SNA has already been mentioned and both the SEEAW and the SNA use the International Standard Industrial Classification of All Economic Activities (ISIC) and the Central Product Classification (CPC). These classifications are at the core of official economic statistics.
2. See section 37/108 of the Report of the 38th Session of the UN Statistical Commission (UN Statistical Commission 2007a).
3. See paragraph 22 of the Report of the Committee of Experts on Environmental-Economic Accounting. 38th Session of the Statistical Commission (UN Statistical Commission 2007b).
4. For example, in the conclusions of the Data for All sessions of the 5th World Water Forum and an OECD workshop Improving the Information Base to Better Guide Water Resource Management Decision Making, on Improving Water Information (Martinez 2009; OECD 2010).
5. See decision 41/108, paragraph (i) of the Report of the 41st UN Statistical Commission (2010).
6. Modified from 2003 SEEA paragraph 2.21 (UN et al. 2003).
7. Paragraph 3.44 of the SEEAW (UN Statistics Division 2007).
8. See World Meteorological Organization and United Nations Educational, Scientific and Cultural Organization (1992).
9. An example of this in practice is Statistics Canada's Standard Drainage Area Classification (SDAC).
10. See SEEAW, paragraph 2.90 (UN Statistics Division 2007).
11. After SEEAW, paragraph 2.90 (ibid.).
12. See Edens et al. (2007).
13. See World Meteorological Organization and United Nations Educational, Scientific and Cultural Organization (1992).
14. See the Report on the Global Assessment of Water Statistics and Water Accounts (UN Statistical Commission 2009).
15. The Murray Darling Basin area and management is described by Slattery et al. in Chapter 1 of this volume.
16. NACE is a European industry standard classification system and ISIC is the UN's International Standard Industrial Classification of All Economic Activities.
17. See the report of the 38th Session of the UN Statistical Commission (2007a).
18. See the Expert Group Meeting on International Recommendations for Water Statistics (UN Statistical Commission 2007b).

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3. Water Footprint Accounting

Arjen Y. Hoekstra

INTRODUCTION

Freshwater is a global resource as a result of international trade in water-intensive goods such as crop and animal products, natural fibres and bio-energy. The use of water resources has, to a great extent, become spatially disconnected from the consumers. Using cotton as an example, from field to final product cotton passes through a number of distinct production stages with different impacts on water resources. These stages of production are often located in different places with final consumption in yet another place. Malaysia does not grow cotton, but imports raw cotton from China, India and Pakistan for processing in the textile industry and exports cotton clothes to the European market (Chapagain et al. 2006). As a result, the impacts of consumption of a final cotton product on the globe's water resources can only be identified by looking at the supply chain and tracing the origins of the product.

The aim of Water Footprint Accounting is to quantify and locate the water footprint of a process, product, producer or consumer or to quantify in space and time the water footprint in a specified geographic area. Uncovering the links between consumption and water use can inform water governance strategies by identifying new triggers for change. Where final consumers, retailers, food industries and traders in water-intensive products have traditionally been out of the scope of those who studied or were responsible for good water governance, with Water Footprint Accounting these players enter the picture now as potential 'change agents'. They are important not only as direct but also as indirect water users.

The water footprint concept was introduced in 2002. Prior to this, there had been few thoughts in the science and practice of water management about water consumption and pollution along whole production and supply chains. As a result, there was limited awareness that the organization and characteristics of a production and supply chain strongly influence the volumes (and temporal and spatial distribution) of water consumption and pollution that can be associated with a final consumer product. Visualizing the hidden water use behind products can assist in understanding the global character of freshwater and in quantifying the effects of consumption and trade on water resources use (Hoekstra and Hung 2005; Hoekstra and Chapagain 2008). The improved understanding can form a basis for a better management of the globe's freshwater resources.

The idea of considering water use along supply chains gained interest after the introduction of the 'water footprint' concept (Hoekstra 2003). The water footprint is an indicator of freshwater use that looks at both direct and indirect water use of a consumer or producer. It can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal. The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. It is a multidimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution. The various components of a total water footprint are specified geographically and temporally. As an indicator of 'water use', the water footprint differs from the classical measure of 'water withdrawal' in three respects. First, it is not restricted to blue water use, but also includes green and grey water. Second, it is not restricted to direct water use, but also includes indirect water use. Third, it does not include blue water use insofar as this water is returned to where it came from. The water footprint thus offers an alternative perspective on how a consumer or producer relates to the use of freshwater systems. It is a volumetric measure of water consumption and pollution. Water Footprint Accounts give spatiotemporally explicit information on how water is appropriated for various human purposes. They can feed the discussion about sustainable and equitable water use and allocation and also form a good basis for a local assessment of environmental, social and economic impacts.

This chapter provides an overview of the new field of Water Footprint Accounting, mostly drawing from the *Water Footprint Assessment Manual* as published by the Water Footprint Network (Hoekstra et al. 2011). The interest in Water Footprint Accounting is highly diverse. Some companies use the water footprint to map their operational and supply-chain water use. Some of the frontrunners in this field are the Coca-Cola Company, SABMiller and Unilever. Investors like the International Finance Corporation consider the concept as a relevant tool to explore the risks of companies associated with water use in their supply chain. A government that has made first steps to incorporate the water footprint into national legislation is Spain, which requires Water Footprint Accounting to be part of drafting river basin plans. Finally, environmental organizations such as WWF and The Nature Conservancy use the concept for awareness raising and pushing governments and businesses towards good water stewardship.

GOALS AND SCOPE OF WATER FOOTPRINT ACCOUNTING

Water footprint studies may have various purposes and be applied in different contexts. Each purpose requires its own scope of analysis and will allow for different choices when making assumptions. When companies apply the water footprint as a metric to quantify their operational and supply-chain water footprint, the target can be, for example, identifying where they contribute to regional hotspots of water overexploitation or pollution, formulating a corporate water strategy, or setting specific quantitative water footprint reduction targets. In the cases where environmental organizations apply the water footprint, they aim at raising awareness in some instances, but other times they go beyond that by aiming at the identification of regional hotspots that need attention or at feeding the debate about the need for water footprint reduction. The purpose for which it is intended determines the water footprint detail required. If the purpose is raising awareness, national or global average estimates for the water footprints of products are probably sufficient. When the goal is hotspot identification, it is necessary to include more detail so that it is possible to exactly pinpoint where and when the water footprint has most environmental, social or economic impacts. If the aim is to have a database for the formulation of policy and establishment of targets on quantitative water footprint reduction, an even higher degree of spatial and temporal detail is required. Further, the water footprint assessment should be embedded in a broader deliberation incorporating factors other than water alone.

Water footprints can be assessed at different levels of spatiotemporal detail as depicted in Table 3.1. At the lowest level of detail, the water footprint is assessed based on global average water footprint data from an available database. At the highest level of detail, water footprint accounts are geographically and temporally explicit, based on precise data on inputs used, and precise sources of those inputs.

The water footprint of one single 'process step' is the basic building block of all Water Footprint Accounts (refer to Figure 3.1). The water footprint of an intermediate product such as cotton lint or a final product

Table 3.1 Spatiotemporal explication in Water Footprint Accounting

	Spatial Explication	Temporal Explication	Source of Required Data on Water Use	Typical Use of the Accounts
Level A	Global average	Annual	Available literature and databases on typical water consumption and pollution by product or process	Awareness raising, rough identification of components contributing most to the overall water footprint, development of global projections of water consumption
Level B	National, regional or catchment specific	Annual or monthly	As above, but use of nationally, regionally or catchment-specific data	Rough identification of spatial spreading and variability, knowledge base for hotspot identification and water allocation decisions
Level C	Locally, site and field specific	Monthly or daily	Empirical data or (if not directly measurable) best estimates on water consumption and pollution, specified by location and over the year	Knowledge base for carrying out a water footprint sustainability assessment, formulation of a strategy to reduce water footprints and associated local impacts

such as a cotton shirt is the aggregate of the water footprints of the various process steps relevant in the production of the product. The water footprint of an individual consumer is a function of the water footprints of the various products consumed by the consumer. The water footprint of a community of consumers is equal to the sum of the individual water footprints of the members of the community. The water footprint of a producer is equal to the sum of the water footprints of the products that the producer delivers. The water footprint within a geographically delineated area is equal to the sum of the water footprints of all processes taking place in that area.

A water footprint is expressed in terms of a water volume per unit of

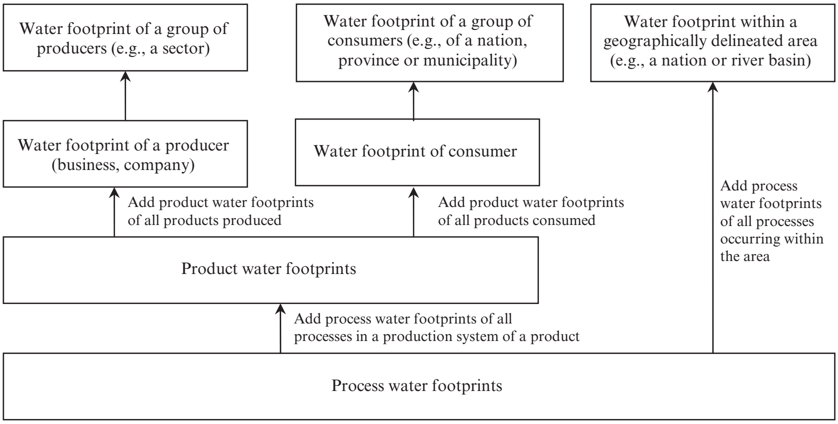

Figure 3.1 Coherence between the different sorts of Water Footprint Accounts

product or as a water volume per unit of time. The water footprint of a process is expressed as water volume per unit of time. When divided over the quantity of product that results from the process, it can also be expressed as water volume per product unit. A product water footprint is expressed in terms of water volume per unit of product (usually m^3/ton or litre/kg). The water footprint of a consumer or producer or the water footprint within an area is expressed as water volume per unit of time, which may be daily, monthly or yearly.

THE WATER FOOTPRINT OF A PROCESS STEP

The blue water footprint refers to consumption of blue water resources (surface- and groundwater) along the supply chain of a product. The term 'consumptive water use' refers to one of the following four cases: (1) water evaporation, (2) water incorporation into a product, (3) water not returning to the same catchment area (for example, it is returned to another catchment area or the sea) or (4) water not returning in the same period (for example, it is withdrawn in a scarce period and returned in a wet period). The first component, evaporation, is generally the most significant one. 'Consumptive water use' does not mean that the water disappears, because most water on earth remains within the cycle and always returns somewhere. Water is a renewable resource, but that does not mean that its availability is unlimited. The blue water footprint measures the amount of water available in a certain period that is consumed. The remainder is left to sustain the ecosystems that depend on the ground- and surfacewater flows.

The green water footprint is the volume of green water (that is, rainwater) consumed during the production process. This is particularly relevant for agricultural and forestry products (such as products based on crops or wood), where it refers to the total rainwater evapotranspiration from fields and plantations plus the water incorporated into the harvested crop or wood.

The grey water footprint of a process step is an indicator of the degree of freshwater pollution that can be associated with the process step. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards. In other words, it refers to the volume of water that is required to dilute pollutants to such an extent that the quality of the ambient water remains above agreed water quality standards. The grey component of water use, expressed as a dilution water requirement, has been recognized by Postel et al. (1996) and Chapagain et al. (2006). The grey water footprint is calculated by dividing the pollutant load (mass/time) by the difference between the maximum acceptable concentration for that pollutant and its natural concentration in the receiving water body (mass/volume). When chemicals are directly released into a surfacewater body, the load can directly be measured. When a chemical is applied on or put into the soil, like in the case of solid waste or use of fertilizers or pesticides, it may happen that only a fraction seeps into the groundwater or runs off over the surface to a surfacewater stream. In this case, the pollutant load is the fraction of the total amount of chemicals applied that reaches the ground- or surfacewater.

When a waste flow concerns more than one form of pollution, as is generally the case, the grey water footprint is determined by the pollutant that is associated with the largest pollutant-specific grey water footprint.

THE WATER FOOTPRINT OF A PRODUCT

The water footprint of a product is estimated by considering water consumption and pollution in all steps of the production chain. Although the water footprint is an indicator that is explicit in time and space, for the purpose of awareness raising and rough comparison of products, total, global average water footprints calculated over a number of years can be presented. Table 3.2 presents global average water footprints of selected commodities.

Table 3.2 The global average water footprint of some selected commodities

Commodity	Unit	Water Footprint (litres)
Apple or pear	1 kg	700
Banana	1 kg	860
Beef	1 kg	15 500
Beer (from barley)	1 glass of 250 ml	75
Bio-diesel from soybean	1 litre	14 000
Bio-ethanol from maize	1 litre	2 600
Bio-ethanol from sugar beet	1 litre	1 400
Bio-ethanol from sugar cane	1 litre	2 500
Bread (from wheat)	1 kg	1 300
Cabbage	1 kg	200
Cheese	1 kg	5 000
Chicken	1 kg	3 900
Chocolate	1 kg	24 000
Coffee	1 cup of 125 ml	140
Cotton	1 shirt of 250 gram	2 700
Cucumber or pumpkin	1 kg	240
Dates	1 kg	3 000
Eggs	1 60-gram egg	200
Goat meat	1 kg	4 000
Groundnuts (in shell)	1 kg	3 100
Leather (bovine)	1 kg	17 000
Lettuce	1 kg	130
Maize	1 kg	900
Mango	1 kg	1 600
Milk	1 glass of 250 ml	250
Milk powder	1 kg	4 600
Olives	1 kg	4 400
Orange	1 kg	460
Paper	1 A4 (80 gram/m^2)	10
Pasta (dry)	1 kg	1 900
Peach or nectarine	1 kg	1 200
Pizza margherita	0.725 kg	1 200
Pork	1 kg	4 800
Potato	1 kg	250
Rice	1 kg	3 400
Sheep meat	1 kg	6 000
Sugar (from sugar cane)	1 kg	1 500
Sugar (from sugar beet)	1 kg	935
Tea	1 cup of 250 ml	30
Tomato	1 kg	180
Wine	1 glass of 125 ml	120

Sources: Hoekstra and Chapagain (2008); Water Footprint Network (2010).

In order to estimate the water footprint of a product it is necessary to specify the production system, which generally consists of some sequential process steps. A (simplified) example of the production system of a cotton shirt is: cotton growth, harvesting, ginning, carding, knitting, bleaching, dying, printing and finishing. In reality, production systems are often complex networks of linked processes, in many cases even circular. If the intention is to go beyond a very superficial analysis based on global averages, the process steps in time and space need to be specified, requiring the origin of the (inputs of the) product to be traced. Production circumstances and process characteristics will differ from place to place, so that place of production will influence the size and colour of the water footprint. Keeping track of where all processes take place is necessary to be able to geographically map the water footprint of a final product.

The water footprint of a product can be calculated in two ways. The simple chain-summation approach can be applied when a production system produces only one output product. In this case, the water footprints that can be associated with the various process steps in the production system can all be fully attributed to the product that results from the system. The water footprint of a product (volume per product unit or mass) is equal to the sum of the relevant process water footprints (volume/time) divided by the production quantity of the product (product units or mass/time). The step-wise accumulative approach is more generic. Suppose we have a number of input products when making another number of output products. The sum of the water footprints of the input products needs to be distributed over the various output products, which can be done proportionally to the value of the output products. Suppose that processing of y input products (i = 1 to y) results in z output products (p = 1 to z). If during processing there is some water use involved, the process water footprint is added to the water footprints of the input products before the total is distributed over the various output products. The water footprint of output product p is calculated as per Equation (3.1):

$$WF_{prod}[p] = \left(WF_{proc}[p] + \sum_{i=1}^{y} \frac{WF_{prod}[i]}{f_p[p,i]} \right) \times f_v[p] \qquad (3.1)$$

where $WF_{prod}[p]$ is the water footprint (volume/mass) of output product p, $WF_{prod}[i]$ the water footprint of input product i and $WF_{proc}[p]$ the process water footprint of the processing step that transforms the y input products into the z output products, expressed in water use per unit of processed product p (volume/mass). Parameter $f_p[p,i]$ is a so-called 'product fraction' and parameter $f_v[p]$ is a 'value fraction'. The product fraction of an output product p that is processed from an input product i is defined as the mass of the output product obtained per mass of input product. The value fraction of an output product p is defined as the ratio of the market value of this product to the aggregated market value of all the output products ($p = 1$ to z) obtained from the input products as depicted in Equation (3.2):

$$f_v[p] = \frac{price[p] \times w[p]}{\sum_{p=1}^{z} (price[p] \times w[p])} \tag{3.2}$$

where $price[p]$ refers to the price of product p (monetary unit/mass). The denominator is summed over the z output products ($p=1$ to z) that originate from the input products.

THE WATER FOOTPRINT OF CONSUMERS

The water footprint of a consumer is defined as the total volume of freshwater consumed and polluted for the production of the goods and services consumed by the consumer. It is calculated by adding the direct water footprint of the individual and his/her indirect water footprint. The direct water footprint refers to the water consumption and pollution that is related to water use at home or in the garden. The indirect water footprint refers to the water consumption and pollution of water that can be associated with the production of the goods and services consumed by the consumer. It refers to the water that was used to produce, for example, the food, clothes, paper, energy and industrial goods consumed. The indirect water use is calculated by multiplying all products consumed by their respective product water footprint (which, for each product, will depend on the origin of the product). The set of products to be considered refers to the full range of final consumer goods and services. The water footprints of final private goods and services are exclusively allocated to the consumer of the private good. The water footprints of public or shared goods and services are allocated to consumers based on the share that each individual consumer takes.

NATIONAL WATER FOOTPRINT ACCOUNTING

Traditional national water use accounts only refer to the water withdrawal within a country (Gleick 1993). They do not distinguish between water use

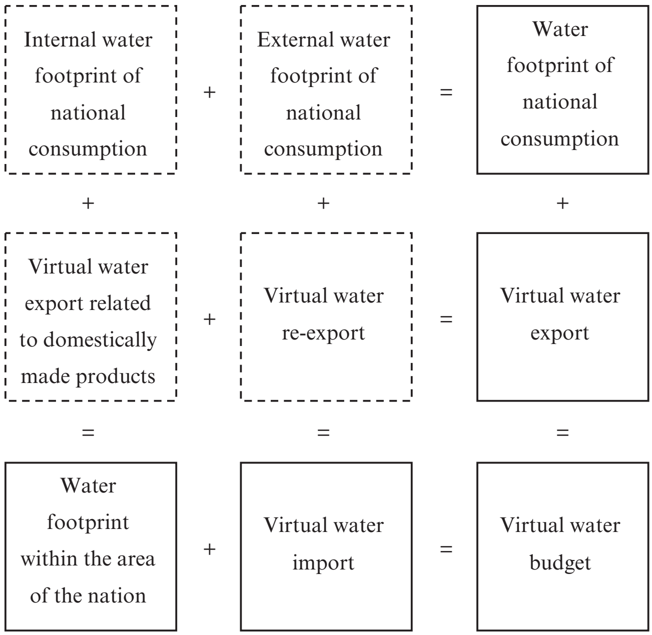

Figure 3.2 The national Water Footprint Accounting scheme

for making products for domestic consumption and water use for producing export products. They also exclude data on water use outside the country to support national consumption. In order to support a broader sort of analysis and better inform, the national water use accounts can be extended. Figure 3.2 is a visual representation of the national Water Footprint Accounting scheme introduced by Hoekstra and Chapagain (2008).

The water footprint of the consumers in a nation has two components. The internal water footprint of national consumption is defined as the use of domestic water resources to produce goods and services consumed by the national population. It is the sum of the water footprint within the nation minus the volume of virtual water export to other nations insofar as related to the export of products produced with domestic water resources. The external water footprint is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation considered. It is equal to the virtual water import into the nation minus the volume of virtual water export to other nations as a result of re-export of imported products.

The virtual water export from a nation consists of exported water of domestic origin and re-exported water of foreign origin. The virtual water import into a nation will partly be consumed, thus constituting the external water footprint of national consumption and partly be re-exported. The sum of the virtual water import into a country and the water footprint within the area of the nation is equal to the sum of the virtual water export from the nation and the water footprint of national consumption. This sum is called the virtual water budget of a nation. Table 3.3 shows the main components of the national Water Footprint Accounts for a number of selected countries compiled by Hoekstra and Chapagain (2007, 2008).

The water footprint within a nation (volume/time) is defined as the total freshwater volume consumed or polluted within the territory of the nation. It can be calculated by summing the water footprints of all water-consuming or polluting processes taking place in the nation. The water footprint of national consumption can be calculated through two alternative approaches. In the top-down approach, the water footprint of national consumption is calculated as the water footprint within the nation plus the virtual water import minus the virtual water export. The gross virtual water import is calculated by multiplying import volumes of various products by their respective product water footprint in the nation of origin. The gross virtual water export is found by multiplying the export volumes of the various export products by their respective product water footprint. The bottom-up approach is based on the method of calculating the water footprint of a group of consumers. The group of consumers consists of the inhabitants of a nation. The water footprint of national consumption is calculated by adding the direct and indirect water footprints of consumers within the nation.

The top-down calculation can theoretically give a slightly higher (lower) figure if the stocks of water-intensive products increase (decrease) over the year. Another drawback of the top-down approach is that there can be delays between the moment of water use for production and the moment of trade. For instance, in the case of trade in livestock products this may happen: beef or leather products traded in one year originate from livestock raised and fed in previous years. Part of the water virtually embedded in beef or leather refers to water that was used to grow feed crops in previous years. As a result of this, the balance presumed in the top-down approach will hold over a period of a few years, but not necessarily over a single year.

The bottom-up approach depends on the quality of consumption data, while the top-down approach relies on the quality of trade data. The outcome of the top-down approach can be very vulnerable to relatively small errors in the input data when the import and export of a country are large relative to its domestic production, which is typical for relatively

Table 3.3 The main components of the national Water Footprint Accounts for some countries for the period 1997–2001 (in Gm^3/yr)

Country	Internal WF of National Consumption	External WF of National Consumption	WF of National Consumption	Virtual Water Export Related to Domestically Made Products	Virtual Water Re-export	Virtual Water Export	Water Footprint Within the Area of the Nation	Virtual Water Import	Virtual Water Budget
Argentina	48	3	52	48	2	51	97	6	102
Brazil	216	18	234	63	5	68	278	23	301
China	826	57	883	67	6	73	893	63	956
Egypt	56	13	70	2	0	3	59	14	72
France	69	41	110	47	31	79	117	72	189
Germany	60	67	127	32	38	70	92	106	197
India	971	16	987	41	1	43	1013	17	1030
Indonesia	242	28	270	23	3	25	265	30	295
Japan	52	94	146	3	4	7	54	98	153
South Africa	31	9	39	6	2	9	37	11	48
UK	22	51	73	5	13	18	27	64	91
USA	566	130	696	184	46	229	750	176	925

Note: Gm^3 = billion cubic metres.

Source: Hoekstra and Chapagain (2007, 2008).

small nations specializing in trade. Van Oel et al. (2009) report the water footprint for the Netherlands using the top-down approach and demonstrate its sensitivity to the import and export data used. Relative small errors in the estimates of virtual water import and export translate into a relatively large error in the water footprint estimate. In such a case, the bottom-up approach will yield a more reliable estimate than the top-down approach. In nations where trade is relatively small compared to domestic production, the reliability of the outcomes of both approaches will depend on the relative quality of the databases used for each approach.

The accounting scheme as described for a nation can also be applied for other geographical units. In general terms, the water footprint within an area is defined as the total freshwater consumption and pollution within the boundaries of the area. The area can be a catchment area, a river basin, a province, state or nation or any other hydrological or administrative spatial unit. The water footprint within a geographically delineated area is calculated as the sum of the process water footprints of all water using processes in the area.

WATER FOOTPRINT OF A BUSINESS

The water footprint of a business is defined as the total volume of freshwater that is used directly or indirectly to run and support the business. The operational (or direct) water footprint of a business is the volume of freshwater consumed or polluted due to its own operations. The supply-chain (or indirect) water footprint of a business is the volume of freshwater consumed or polluted to produce all the goods and services that form the inputs of production of the business. A further differentiation is possible between the water footprint that can be immediately associated with the product(s) produced by the businesses and the 'overhead water footprint'. The latter is defined as the water footprint pertaining to the general activities for running a business and to the general goods and services consumed by the business. The term 'overhead water footprint' is used to identify water consumption that is necessary for the continued functioning of the business but that does not directly relate to the production of one particular product. In every case, the green, blue and grey water footprint component can be distinguished. Examples of the various components in a business water footprint are given in Table 3.4.

In addition to the operational and supply-chain water footprint, a business may distinguish an 'end-use water footprint' of its product. This is the water consumption and pollution by consumers when using the product. Strictly speaking, the end-use water footprint of a product is not part of

Table 3.4 Examples of the components of a business water footprint

Operational Water Footprint		Supply-chain Water Footprint	
Water footprint directly associated with the production of the business's product(s)	Overhead water footprint	Water footprint directly associated with the production of the business product(s)	Overhead water footprint
Water incorporated into the product Water consumed or polluted through a washing process Water thermally polluted through use for cooling	Water consumption or pollution related to water use in kitchens, toilets, cleaning, gardening, or washing working clothes	Water footprint of product ingredients bought by the company Water footprint of other items bought by the company for processing their product	Water footprint of infrastructure (construction materials etc.) Water footprint of materials and energy for general use (office materials, cars and trucks, fuels, electricity, etc.)

the business water footprint or the product water footprint, but part of the consumer's water footprint. Water consumption or pollution by a consumer when using a product depends on the habits of the consumer, but sometimes it also depends on the characteristics of the product. For example, the water pollution that results from the use of soaps in the household depends on the ingredients of the soap and the harm they can do when discharged into ambient water. Companies can influence this through the design of their products.

Business Water Footprint Accounting can inform the development of a well-informed corporate water strategy because the water footprint as an indicator of water use differs from the indicator 'water withdrawal in the own operations' currently used by many companies. Companies have traditionally focused on water use in their operations, not in their supply chain. Most companies will discover that their supply-chain water footprint is much larger than their operational footprint. It may be more cost effective to shift investments from efforts to reduce operational water use to efforts to reduce the supply-chain water footprint and associated risks.

For business Water Footprint Accounting, it is necessary to define the business units that will be considered and specify the annual inputs and outputs per business unit (in physical units). The operational water footprint of a business unit is equal to the consumptive water use and the water pollution that can be associated with the operations of the business. A simple approach is to include the evaporative flow from the operations, the volume of water incorporated into products and the return flows of water to catchments other than from where water was withdrawn. In addition, the effluent volumes and concentrations of chemicals therein should be considered. The operational overhead water footprint (water consumption and pollution related to general water-using activities in the business unit) can be identified and quantified just like the operational water footprint directly associated with the production process. The overhead water footprint, however, will often serve more than the business unit considered. For example, the overhead of a factory with two production lines will have to be distributed over the two production lines. If a business unit refers to one of the production lines, the share of the overhead water footprint that is to be apportioned to that production line can be estimated based on the production value of that production line relative to the value of the other production line.

The supply-chain water footprint per business unit (volume/time) can be calculated by multiplying the various input product volumes (that is, data available from the business itself) by their respective product water footprints (that is, data obtained from suppliers). The product water footprint depends on the source of the product. When the product comes from another business unit within the same business, the value of the product water footprint is known from the business's accounting system. When the product originates from a supplier outside the own business, the value of the product water footprint has to be obtained from the supplier or estimated based on indirect data known about the production characteristics of the supplier. The various product water footprints are the aggregation of the green, blue and grey footprints. Accordingly, the supply-chain water footprint for a business unit can be disaggregated into its blue, green and grey components.

The water footprint of each specific output product of a business unit (volume/product unit) is estimated by dividing the business unit water footprint (volume/time) by the output volume (product units/time). Allocation of the water footprint over the output products can be done in several ways, for example, according to mass, energy content or economic value. Following what is common in life-cycle assessment studies, it is recommended to allocate according to economic value. The rationale behind this economic allocation is that the final economic value obtained is the reason for the use of resources and thus the water footprint. Therefore, it is reasonable to allocate the total water footprint to a greater extent to the primary products of a process and to a lesser extent to the (lower value) secondary or by-products.

CONCLUSION

Traditional statistics on water use, whether national or corporate accounts, are mostly restricted to water withdrawals, thereby ignoring green and grey water use and disregarding indirect use as well. In the case of business accounts, the traditional approach pays no attention to water consumption and pollution in the supply chain. In the case of national accounts, the conventional approach overlooks virtual water imports and exports and the fact that part of the water footprint of national consumption lies outside the country. It is desirable to gradually start incorporating water footprint statistics in governmental statistics and featuring them in international statistics. In the case of companies, it is desirable to incorporate Water Footprint Accounts in corporate environmental and sustainability reporting. In this way, governments and companies have a more comprehensive picture of their direct and indirect appropriation of freshwater resources, enabling them to develop better-informed water policies.

The water footprint, introduced in 2002 (Hoekstra 2003), is part of a family of footprint concepts. The oldest footprint concept is the ecological footprint, introduced in the 1990s by Rees (1992) and Wackernagel and Rees (1996). The ecological footprint measures the use of available bioproductive space and is measured in hectares. The carbon footprint concept originates from the ecological footprint discussion and has started to become more widely known since 2005 (Safire 2008). The carbon footprint refers to the sum of greenhouse gas emissions caused by an organization, event or product and is expressed in terms of CO_2 equivalents. Although the carbon footprint concept is relatively young, the idea of accounting greenhouse gas emissions is already much older; the first assessment of the Intergovernmental Panel on Climate Change, for example, already dates back to 1990. Older than the ecological and carbon footprint concepts are also the concepts of 'embodied energy' and 'emergy' as applied in energy studies (Odum 1996; Herendeen 2004). These concepts refer to the total energy used to produce a product and are expressed in joules.

The various 'footprint' concepts are to be regarded as complementary indicators of natural capital use in relation to human consumption (Hoekstra 2009). Looking at only area requirements or only water or energy requirements is insufficient. Available land, freshwater and energy are all critical factors in development. A challenge for future research is to bring the various footprint concepts and related methods together in one consistent conceptual and analytical framework. A further challenge is to link water footprint accounts to material flow analysis, input–output modelling (Zhao et al. 2009) and life cycle assessment (Milà i Canals et al. 2009).

The water footprint is a relatively new concept and Water Footprint Accounting is a method only recently recognized as a useful tool by both governments and companies. In practical implementation, various challenges remain, including the development of practical guidelines per product category and business sector on how to truncate the analysis (where to stop going back along supply chains) and rules on how to account for uncertainties and how to deal with time variability when doing trend analysis. The challenge is to develop databases on typical process water footprints (the basic ingredient for each analysis) and tools to make it easier for practitioners to set up a water footprint account.

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4. Water accounting to assess use and productivity of water: evolution of a concept and new frontiers

Poolad Karimi, David Molden, Wim Bastiaanssen and Xueliang Cai

INTRODUCTION

Coping with water scarcity requires improvement in the way that water is managed in most areas of the world. Underpinning water management is the basic information on the availability and use of water resources. However, reliable information about water resources is hard to obtain for several reasons, one of which is availability of data. Even where data are available the task of identifying who uses how much water remains difficult because of hydrologic complexities of water use, storage and water reuse, especially in heavily developed river basins.

The objective of the chapter is to introduce the International Water Management Institute (IWMI) Water Accounting Framework (IWMI WA), developed in 1997, and recent developments related to this water accounting system. IWMI WA provides information on supply and use of water and relates water use to the economy. It is a multiscale method to account for the amount of water available, how much is used by various sectors and the value derived from the use to promote understanding of water use and assist with improved water management. In illustrating the IWMI WA system, concepts and definitions plus examples from different areas and scales are discussed in this chapter.

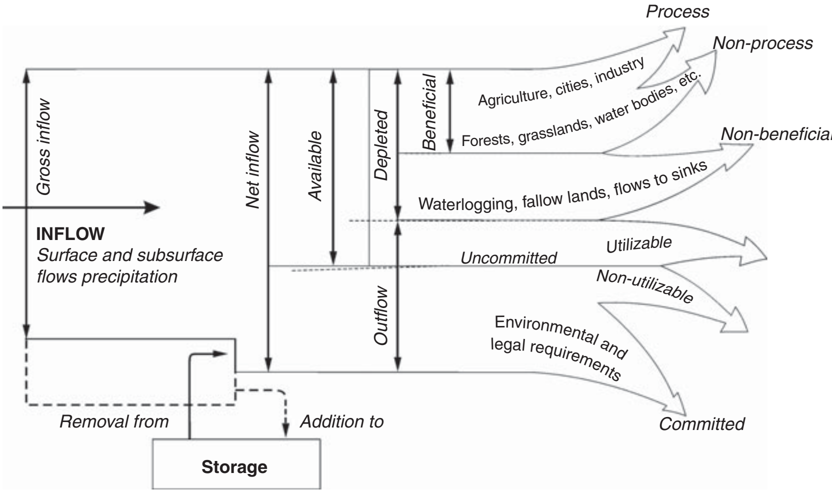
In a basin context, water accounting defines water availability and helps users to understand water use and benefits and costs derived from its use. This information helps to identify opportunities for improved water management, water savings and increasing the value derived from water use. Water accounting is useful to assist water managers and policy-makers develop strategies for improved allocation of water and methods to improve the benefits derived from water. This water accounting procedure was originally derived to better understand how irrigation systems operate within river basins, but remains relevant for all uses of water in a basin context. This procedure differs from General Purpose Water Accounting, which is designed to report information about water, and rights and obligation to water, to external parties for decision-making (Slattery et al., Chapter 1 this volume).

IWMI WATER ACCOUNTING

A water accounting tool was developed at IWMI (Molden 1997; Molden et al. 2001) in response to a need for a tool that helps to identify effective strategies for water saving and enhancing the productivity of water and also to ease the water-related dialogue between professionals and non-water professionals. The tool, IWMI WA, is based on a water balance approach and in the procedure translates water balance components, inflows and outflows, into various water accounting categories such as net inflow, process consumption, non-process depletions, committed outflow and uncommitted outflows (see Molden et al. 2001 for detailed definitions). A main difference between IWMI WA and other common water accounting frameworks, such as the UN System for Environmental-Economic Accounting for Water (SEEAW) (UN 2003), is the use of water consumption instead of water withdrawals. Such an approach helps to track water reuse as it accounts for consumed water (for example, evapotranspiration) rather than diverted flow to a domain. However, it does not report on water withdrawals and the efficiency of water use.

IWMI WA can be applied at all scales of interest and requires the definition of a domain bounded in three-dimensional space and time. For example, at a river basin scale, this would include the lateral basin boundaries, the top of the crop canopy and the bottom of an aquifer taken over a specified time period. At field scale, this could be the top of the plant canopy to the bottom of the root zone, bounded by the edges of the field, over a growing season. The task in water accounting is to estimate the flows across the boundaries of the domain during the specified time period.

Three main scales identified for analysis are the basin, service level and field scale. The procedure considers inflows, storage change and depletion of water. Depletion of water is defined as a use of water rendering it unavailable for further use downstream. Water is depleted by evaporation, flows to sinks, incorporation into products, or degradation of quality. This is different from other approaches that account for water withdrawals. The advantage of using depletion over withdrawals is that it is hard to



Source: Molden et al. (2003).

Figure 4.1 Generalized water accounting diagram, applicable to analysis at basin and other scales

estimate return flows and recycling of water within the system. By focusing on flows across the domain boundaries, withdrawals and recycling are internalized within the IWMI WA.

Figure 4.1 depicts generalized water accounting applicable to analysis at basin and other scales. The inflow to most basins is only precipitation. Nevertheless, for cases where inter-basin transfers or subsurface flows exist, the inflow is comprised of precipitation plus surface and subsurface inflows. A distinct feature of the IWMI WA is the inclusion of precipitation in the basin water accounting analysis instead of only looking at generated flow. This provides an opportunity to capture benefits derived from the rain and have a wider view over options of enhancing productivity of overall water supplies. Land use changes are then captured. This is important as they alter patterns of water availability.

At the basin scale, water is depleted through different process and non-process uses. Process uses of water intended for a particular human use include agricultural, industrial and domestic uses. Depletion by ecosystems that provide valuable goods and services also can be counted as process depletion. If water is diverted and kept in ponds for fish, the surface evaporation from the pond is accounted for as water depleted by fisheries. All the process uses fall under beneficial uses as water is consumed to produce an intended good.

Non-process water use comprises all the depletions that are not intended. A portion of non-process depletion could be beneficial such as evapotranspiration (ET) from natural vegetation, including grasslands and forests, or evaporation from water bodies and wetlands. There are also non-beneficial uses like flows to sinks (saline groundwater, seas, oceans, evaporation ponds/playas) and evaporation from soil surfaces, weeds and water rendered unusable due to degradation of quality.

Outflows from a basin require special consideration as they give an initial indication of how much additional water is available for use. In a basin some outflow is required to maintain an environmental balance. Moreover, water rights may dictate that flows are to be released to go downstream. The IWMI WA calls these 'committed outflows'. It is nearly impossible to capture some outflows. For example, a high flow that cannot be captured by existing facilities is considered non-utilizable. The remaining water is considered utilizable for within-basin use. So even if outflows exist, they may not represent water that could be developed if they are already committed or non-utilizable.

Within an irrigation system there are natural inputs including rainfall, non-managed surface and subsurface flows and managed irrigation supplies. In addition to the intended depletion by crop transpiration, water is also depleted by evaporation from trees, fallow land, other vegetation and water bodies, much of which can be considered beneficial. Drainage flows are considered depleted when they are directed to sinks or become so polluted that there is no opportunity for reuse. The amount of water that could be saved or redirected to a process use is represented by depletion from fallow land and uncommitted outflows.

At the field scale, water enters the domain by rain, by subsurface flows and when irrigation is available through irrigation supplies. Water is depleted by the process of growing plants, namely transpiration and evaporation. The remainder flows out of the domain as surface runoff, subsurface flows or is retained as soil-moisture storage.

WATER ACCOUNTING INDICATORS

Numerous indicators are derived from this water accounting procedure. The overall philosophy of the indicators is to first provide a set of fractions that give an indication of water use, but do not have a value statement attached to them. A second group of indicators allowing for valuation and for agricultural use is referred to as the productivity of water indicator group. These indicators include the following:

1. *Depleted fraction (DF)* is that part of the inflow that is depleted by both process and non-process uses. Depleted fraction is defined as the depleted water divided by the net inflow.
2. *Process fraction (PF)* relates process retain depletion to either total depletion or the amount of available water. It is defined as the process depletion divided by the available water.
3. *Water productivity (WP)* can be related to either the physical mass of production or the economic value of produce per unit volume of water (Molden et al. 2010). Water productivity can be measured against gross or net inflow, depleted water, process-depleted water or available water.

EXAMPLE OF IWMI WATER ACCOUNTING APPLICATION

The IWMI WA has been applied to assess productivity of water use in several basins across the globe at various scales. Examples of applications include Egypt's Nile (Molden et al. 1998), China's Yellow River basin (Zhu et al. 2004; Khan et. al. 2007), India's Krishna basin (Biggs et al. 2007), Nepal's Indrawati basin (Bhattari et al. 2002), Indonesia's Singkarak-Ombilin River basin (Peranginangin et al. 2003) and Zhang He Irrigation District in China (Loeve et al. 2004; Dong et al. 2004). For illustration, the Karkheh River basin example is discussed below.

Karkheh River Basin

Iran's Karkheh River basin is a water-scarce basin. Occupying 51 000 km^2 of land, it is playing a vital role in Iran's agricultural policy of wheat self-sufficiency by producing about 12 per cent of the country's wheat. Outflows of the basin are fundamental for existence of the Hoor-al-Azim swamp, which is a Ramsar site (Wetlands of International Importance) at the border of Iran and Iraq. The basin water accounts are shown in Table 4.1. Values used in the accounts are based on official statistics. The gross inflow to the basin is 24.55 billion cubic metres (bcm),[1] which all comes from precipitation. Subsurface storage balance in the basin is negative, implying that the groundwater exploitation rate in the basin is higher than the recharge rate.

Total water depletion is estimated at 20.5 bcm, out of which 5.17 bcm is process depletion for crops. Depletive use by agriculture is about 4.87 bcm. Non-process depletion, equal to 15.33 bcm, accounts for almost 75 per cent of the total water depletion in the basin. Evapotranspiration

Table 4.1 IWMI application – basin-level accounts for the Karkheh River basin (long-term average)

	Component Value (bcm)	Total (bcm)
Inflow		
Gross inflow		24.55
Precipitation	24.5	
Surface inflow	0	
Subsurface inflow	0	
Storage change		−0.06
Surface	0	
Subsurface	−0.06	
Net inflow		24.61
Depletive use		
Process		5.17
Agriculture	4.87	
M&I	0.3	
Non-process		15.33
Evapotranspiration	14.91	
Evaporation from open surface and groundwater	0.42	
Total depletion		20.5
Outflow		
Total outflow		4.05
Surface outflow	4.05	
Subsurface outflow	0	
Committed water		2.2
environment (assumed)[a]	2.2	
Uncommitted outflow	4.05–2.2	1.85
Available water	24.61–2.2	22.41
Indicators		
Depleted fraction (net)	20.5/24.61	0.83
Depleted fraction (available)	20.5/22.41	0.91

Notes:
bcm = billion cubic metre; ET = evapotranspiration; M&I =Municipal and Industrial.
a. Assumed based on the average estimated committed outflow for Karkheh by Masih et al. (2009).

Source: Water Resource Management Department, Power Ministry of Iran.

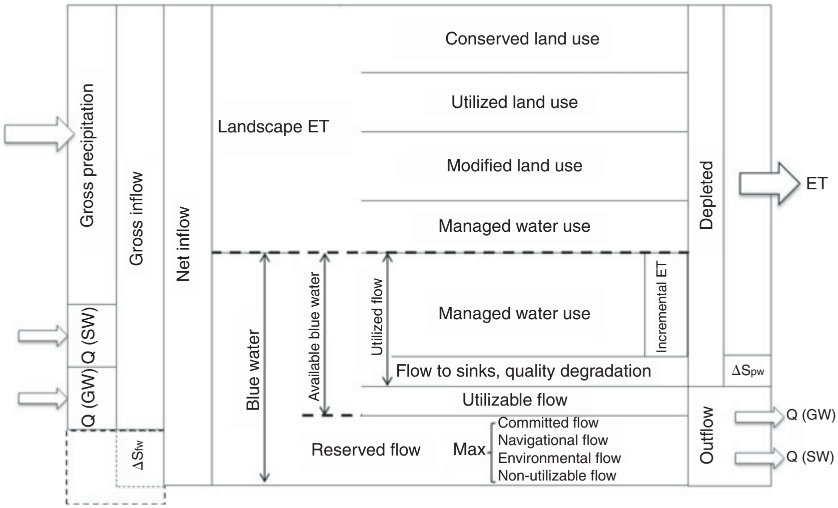
(ET) from different land uses including rangelands, bare lands, fallow and waterlogged land and forests, comprises 14.91 bcm of the non-process depletion. There is no known groundwater outflow from the basin and surface outflow constitutes all outflows from the basin. Estimated outflow for an average year is 4.05 bcm. The depleted fraction of the net inflows for the basin is 0.83, indicating that much of the inflows are depleted through different processes in the basin. Despite the high depletion fraction, the process fraction is relatively low in the Karkheh and it is estimated at only 0.21, implying that a large portion of depleted water in the basin goes to unintended purposes with often negligible or low productivity. This is especially important considering the fact that Karkheh is a water-scarce basin and it is predicted that it will receive significantly less rainfall in future due to climate change. This gives an indication that there are opportunities for more water control in the basin, either through better management of rainfall or capturing more water for irrigation.

WATER ACCOUNTING PLUS (WA+)

Water Accounting Plus (WA+) is a new framework that uses the IWMI WA principles while updating some of the key concepts and provides explicit information on water depletion process based on land use classifications. This new water accounting moves past the idea of irrigation in a basin context, to a more robust multi-use analysis.

In WA+, the categories remain the same (that is, process or non-process and beneficial or non-beneficial) despite the fact that a basin is far more complicated than an irrigation system. Some definitions that are quite specific at irrigation service level seem to be generic at basin scale, while others do not provide adequate information. For instance, process consumption at irrigation service scale represents only crops' ET while at basin scale it includes irrigated and rain-fed crops, municipal and industries, fisheries, forestry, dedicated wetlands and all other intended uses. However, IWMI WA does not differentiate which water sources go to each use (in other words, it is hard to know how much ET comes from rain versus irrigation). WA+ provides information about use and productivity of each item separately to assist water specialists and policy-makers to better understand the situation and possible ways of improvement. WA+ also addresses the link between land use and water use to provide a more complete picture of water use and availability.

The WA+ offers improvements to the earlier work in the basin scale analysis. The improvements include:



Note: ET = evapotranspiration,Q (GW) = groundwater inflow, Q (SW) = surface water inflow, ΔSpw = polluted water storage change and ΔSfw = freshwater storage change.

Figure 4.2 WA+ framework

1. separation among managed, manageable and non-manageable flows;
2. separation of consumed water (ET) to transpiration, evaporation and interception;
3. consumptive use related to land use classes; and
4. extended analysis on flow to explicit surfacewater and groundwater resources.

A key feature of WA+ is that the approach is amenable to remote sensing analysis, thereby minimizing the amount of data collection needed from in the field. Remote sensing techniques can separate actual evaporation from actual transpiration in order to give a deep insight into beneficial transpiration processes by crops and other land covers. For instance, excessive soil evaporation and interception from agricultural land can be considered as non-beneficial.

The WA+ framework is displayed in Figure 4.2. One of the major differences between WA+ and IWMI WA is that the process depletion is now expressed explicitly into various types of ET volumes. The landscape ET is a consequence of rainfall, floods, land use, soil type, slope, elevation, drainage and other physical processes and properties that occur without anthropogenic interferences. This vaporized water is not available for downstream withdrawals and water resources development, unless land use changes and water conservation practices are introduced. This highlights that water budgets can be managed from land use changes.

The ET of conserved land use relates to the ET of natural ecosystems such as national parks, wetlands and tropical rainforests. These natural ecosystems should not be modified without having very strong incentives and arguments. The land use category 'utilized land use' relates to a low to moderate resource utilization, such as savannah, woodland and mixed pastures. The returns from utilized land use are often limited to livestock, wildlife and fuel woods and the anthropogenic influence is limited. Modified land use relates to the replacement of the original vegetation for increased utilization of land resources. Examples are rain-fed plantation forests, rain-fed crops and rain-fed pasture. Water diversions and abstractions do not take place in modified land use, but the ET process differs from the original ET patterns and stream flow is altered. The category 'managed water use' represents landscape elements that receive withdrawals from the blue water system by constructed infrastructure. This relates to water withdrawals for irrigation, aquaculture, domestic use and industries, among others. These flows are often discussed when securing the domestic water supply and meeting the Millennium Development Goals. Obviously, this is only a fraction of the total water use picture.

WA+ Application: The Nile Basin

To illustrate the WA+ framework, an example from the Nile basin is utilized. The period of the water account is from 1 January 2007 to 31 December 2007. Land use data, precipitation data and ET data are all derived from remote sensing techniques and used as input data. Table 4.2 illustrates the Nile basin water accounts. The net inflow to the Nile basin was estimated at 2048 bcm. Surface and subsurface inflows to the basin were negligible and 2045 bcm out of 2048 bcm came from precipitation. The remaining 3 bcm came from the freshwater storage, with 2 bcm from surface storage and 1 bcm from subsurface storage.

Total depletion for the period was estimated at 2015 bcm. Of this, 1955 bcm was depleted through natural landscape ET and the remaining 60 bcm through utilized flows. Further breakdown of water depletion of landscape ET showed utilized land use consumes the majority of the depleted water in the Nile. ET over this land use class was as high as 1594 bcm, followed by 199, 151 and 11 bcm respectively for modified land use, conserved land use and managed water use. Incremental ET of the managed water use class was estimated at 59 bcm, indicating the amount of artificially diverted water that

Table 4.2 WA+ application – basin-level accounts for the Nile River basin

	Component Value (bcm)	Total (bcm)
Inflow		
Gross inflow		2045
Precipitation	2045	
Surface inflow	0	
Subsurface inflow	0	
Freshwater storage change		−3
Surface	−2	
Subsurface	−1	
Net inflow		2048
Depleted water		
Landscape ET		1955
Conserved land use	151	
Utilized land use	1594	
Modified land use	199	
Managed water use	11	
Utilized flow		60
Managed water use (Incremental ET)	59	
Flow to sink	1	
Total ET		2014
Total depletion		2015
Outflow		
Outflows		
Surface outflow	28	
Subsurface outflow	5	
Reserved outflow		8
Committed flow	0.0	
Navigational flow	1.8	
Environmental flow	8	
Non-utilizable flow	1.2	
Utilizable outflow	33–8	25
Blue water		93
Available blue water	93–8	85
Total outflow		33

Note: bcm= billion cubic metre; ET = evapotranspiration.

had been evapotranspired in the period. Flow to sinks was assumed to be around 1 bcm (1 per cent of blue water) in the Nile.

The Nile Basin water account shows only 4 per cent of the total rainfall (93 bcm) goes to blue water (that is, the water in rivers, lakes and groundwater). The total outflow from the basin in the year of study was about 33 bcm: 28 bcm in the form of surface outflow and 5 bcm subsurface outflow. Indeed the estimated surface outflow is well in line with the reported annual average river outflow of about 30 bcm by Bonsor et al. (2010), however, it is more than previously reported by Molden et al. (1998). Committed outflow was estimated to be at around 8 bcm for environmental purposes, although this remains a rough estimate (Molden et al. 1998). This implies that there was approximately 25 bcm of utilizable water that could be tapped to expand managed water use; however, a more detailed analysis would be required to determine this.

In summary, of the 2048 bcm net inflow to the basin, 98 per cent (2015 bcm) is depleted by different uses within the basin with the remaining 33 bcm leaving the basin. This illustrates that the Nile basin is almost a closed basin and real options for future water issues reside with land use changes including more intensive rain-fed agriculture. This analysis indicates that in 2007 there was a significant amount of utilizable outflow, indicating potential for more managed water use by cities, industries or irrigation within the basin. This is important information for overall basin planning. To verify this, more years of water accounting analysis are required to determine if this was an unusually wet year and what climate change impacts could be. This is all important information as Nile countries debate where and how much more water should be developed.

This Nile example used remotely sensed data as input to WA+ instead of flow measurement and field data, demonstrating that it is possible to account for water even in areas where acquiring data is a challenge. It also eases the water accounting procedure for large transboundary basins. However, satellite-driven data are associated with uncertainties that could affect the water accounting indicators accuracy. Therefore, further research is required to investigate impacts of these uncertainties on water accounting indicators.

CONCLUSION

Better management to gain more value from existing water supplies is a vital key for coping with water scarcity. However, the ability of policymakers to develop effective strategies in water management depends highly on understanding the state of water use and productivity in a basin.

The IWMI WA is a tool to account for the amount of available water in a domain and report on the volume of water used by various sectors. The framework provides information on the amount of water used by various uses and the value that is derived from these uses. Furthermore, it helps to understand future options for water interventions. The framework's output tables and graphs assist water managers and policy-makers to develop strategies for improved water allocations and optimizing the benefits derived from water.

Since its development, IWMI WA has been applied in a number of studies and proved to be a promising tool in accounting for water use. This experience provides a basis for further improvement and enhancements. The WA+ methodology has been proposed to advance IWMI WA, updating key terminologies and concepts. Consistent with IWMI WA, WA+ examines depletion or consumption rather than withdrawals to help to address internal water reuses in a basin. It provides information on water use in different land use categories to identify opportunities for interventions resulting in water savings and increased productivity of water. Moreover, WA+ information can be obtained almost solely from satellite remote sensing. Examples of water accounting in the Karkheh basin and the Nile demonstrate that the approach is valuable in a range of settings, including major transnational river basins, to provide an important view on water availability and its use.

NOTE

1. 1 bcm = 10^6 megalitres.

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PART II

Application and evaluation of water accounting systems

5. Water accounting in mining and minerals processing

Claire M. Cote, Jason Cummings, Chris J. Moran and Kristina Ringwood

INTRODUCTION

The minerals industry interacts with water in many different ways, through its own water use, waste disposal and issues associated with the dewatering of underground mines or of open-cut pits that intersect the water table. Large volumes of water are used for processing and transport of ore and waste, minerals separation, dust suppression, washing of equipment and human consumption (van Berkel 2007; Department of Resources, Energy and Tourism (DRET) 2008). Relatively speaking, the industry uses low volumes of water to accomplish these tasks when considered on a global or national scale. For example, the mining industry accounts for 2 per cent of Australia's water use (Australian Bureau of Statistics (ABS) 2006). In specific regions though, a mining operation may use a higher percentage of locally available water than the national averages would suggest. Mining companies recognize that initiatives to better manage water resources beyond duty of care requirements reflect on their 'social licence to operate'. Accordingly, there has been an increasing effort to invest in water resource management far beyond mandated requirements.

Water is a key business asset in mining that requires planning to ensure water supply security from an operational perspective. Securing water supply means that most mining operations must store water in dams or mining voids. In wet climates or situations of water abundance, extreme rainfall events can cause these storage facilities to discharge surplus water into local water bodies. As well, even in cases where an operation benefits from high average rainfall, there can be instances of local and punctual scarcity. Mining also disposes of large volumes of wastewater once valuable products such as metal, diamonds or coal have been extracted. Waste disposal usually occurs in tailings dams. These dams often hold large volumes of water and are subject to water loss through evaporation and seepage. One of the characteristics of mining industry water use is that it does not necessarily require high-quality water, or what is commonly referred to as freshwater. The communication of water use in mining cannot be divorced from considerations of water quality and local and regional values of water.

The mining industry engages broadly with stakeholders but stakeholders' information needs differ. At the global level, commitment to sustainable water management is encapsulated in the industry's adoption of a formal approach to develop and adopt sustainable development principles through global accords that are reflected in company policies and that are reported annually (International Council of Mining and Minerals (ICMM) 2003). This process achieved the development of a sustainability framework comprising three elements: a set of ten principles; independent assurance; and public reporting, for instance via the Global Reporting Initiative (Global Reporting Initiative (GRI) 2005). Companies use the GRI Mining and Metals Sector Supplement to guide the calculation of the core water indicators across sites in a consistent manner. However, the gap between a site's operational water balance and a GRI report card for water use remains vast, from philosophical, technical and stakeholder requirement perspectives (Mudd 2008). Most companies produce their GRI indicators by compiling and aggregating data collected at site level, and this requires substantial effort because there is no consistent format for the production of site-level data. Corporate departments find that they have to aggregate data that cannot easily be added, which is often an issue in social and environmental accounting as it requires adding possible apples to approximate pears and subtracting the result from hypothetical oranges (Bebbington and Gray 2001 p. 577).

At the national and state levels in Australia, policies and regulations are applied to provide a process to determine water access entitlements. The focus tends to be placed on how water is accessed and not on how it is managed. The water sector in Australia is experiencing reforms associated with the National Water Initiative (NWI) but there is an ongoing challenge to reconcile emerging requirements with pre-existing minerals industry regulation and leading practice.

At the level of a mining or minerals processing operation, water information is usually gathered as part of operational performance (to manage supply to a processing plant), engineering designs (to build a dam), environmental reporting for regulatory requirements and as part of broader company policies typically expressed through the health, safety, environment and community (HSEC) data compilation. This information is collected by a range of teams and can be embedded in highly technical documents. Moreover, whilst many operations and companies already have in place methods for measuring, monitoring and reporting water use, they are rarely consistent across operations within companies, across companies within the minerals industry, or consistent with the way other sectors report water use, duplicating the effort required in communicating water-related information. Therefore, there is a clear need for water accounting that will provide information that is consistently reported and can be used in a range of contexts and for a range of audiences, such as corporate and global reporting and engagement with local stakeholders.

This chapter describes the proposed water accounting for the Australian minerals industry. The Minerals Council of Australia (MCA) undertook a water accounting research and development project in conjunction with the Sustainable Minerals Institute at the University of Queensland from 2007 to 2009. The system has been piloted in partnership with the New South Wales Minerals Council at a number of operations in Australia with the results developing and refining the water reporting system. The reporting proposes a standard representation of water balance and operational efficiencies at the level of a mining or mineral processing operation. The application includes tables listing the physical flows entering and leaving the operation, the reuse and recycling flows and the accuracy of the flows. The information produced in these tables can be used to generate water accounting reports for the reporting entity.

The methodology used to develop water accounting for the Australian minerals industry is presented. This methodology involved reviewing the most prominent existing accounting frameworks to ensure that the proposed terms and definitions would meet current reporting requirements. The adopted terms and definitions included metrics that required a calculation methodology (for example, evaporation), which was developed based on a systems approach (Cote and Moran 2009). A pilot project was then undertaken with five mines from the Central New South Wales region, which tested the water accounting against a range of key contextual factors such as climate, commodity, maturity and process.

REQUIREMENTS EMERGING FROM EXISTING WATER ACCOUNTING FRAMEWORKS

There are several existing and emerging frameworks for 'water use reporting', including, but not limited to: the GRI, the United Nations System of Environmental-Economic Accounting for Water (SEEAW) (United Nations Statistical Division (UNSD) 2006; Smith 2007), Water

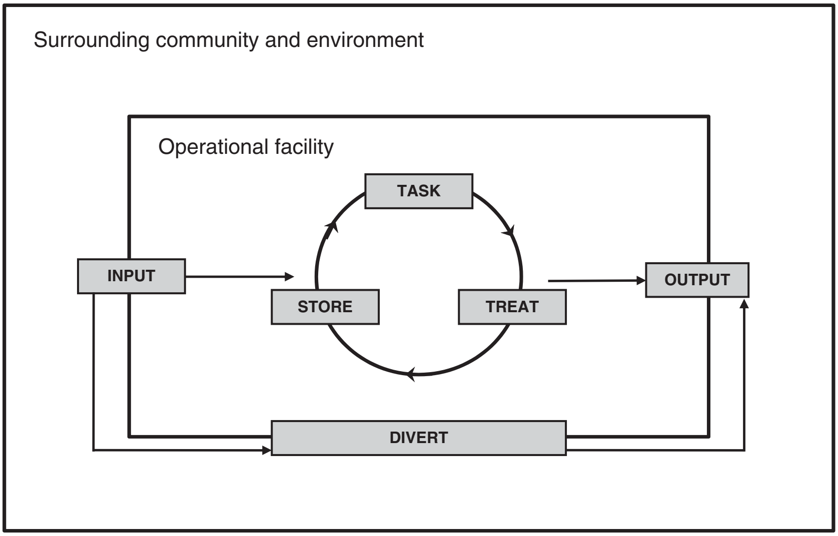
Footprint Accounting (WFA) (Hoekstra et al. 2009) discussed in Chapter 3 of this book and the Water Accounting Conceptual Framework for the Preparation and Presentation of General Purpose Water Accounting Reports (Water Accounting Standards Board (WASB) 2009) underpinning the General Purpose Water Accounting discussed in Chapter 1 of this book. Key points of consideration in framing water accounting for mining and minerals processing include the following:

1. A requirement to account for the various sources of water. Surfacewater and groundwater are to be documented as separate water flows.
2. A need to consider water quality, but no consistent guidelines for doing it.
3. The status of water volumes held in stores needs to be known.
4. Reuse and recycling are not always distinguishable; there are inconsistencies and inaccuracies between and within some water accounting systems (such as SEEAW and GRI); and the collection of rainwater for on-site purposes is currently considered reuse under the GRI definitions, when clearly, it has not been previously used. There needs to be a robust platform for the consistent calculation of the reuse/recycling component that does not rely on circular and conflicting definitions.
5. The definition of use and abstraction can be different depending on the basis for accounting. Some frameworks (such as SEEAW) clearly recognize water flows that are not for consumptive use. The WFA considers the total volume of freshwater that is used directly and indirectly to run and support the business.

Many existing frameworks are concerned with reporting water flows at macro levels: national (SEEAW), corporate (GRI) and supply chain (WFA). Akin to General Purpose Water Accounting, the mining industry water accounting system aims at reporting water flows at the level of a mining operation but in such a way that they can be aggregated to produce information for macro levels (corporate and national).

MINING INDUSTRY WATER ACCOUNTING: AN OVERVIEW

Water accounting for the Australian mining industry is founded in a concept model that relates an operational facility's water interactions with the surrounding environment and community as depicted in Figure 5.1. The concept model at this level is comprised of four functional elements:



Source: Department of Resources, Energy and Tourism (DRET) 2008.

Figure 5.1 Water system concept model for accounting purposes

1. input, representing the receipt of water to the operational facility;
2. divert, moving water around or through the operational facility;
3. task–treat–store cycle, representing the operational tasks associated with minimizing losses, managing climate variability and implementing efficient technologies and processes; and
4. output, representing the removal of water from the operational facility.

The water reporting proposed comprises a Statement of Inputs and Outputs, water quality descriptions and a Statement of Operational Efficiencies. The standard accounting period is one year but the system can be applied at shorter or longer intervals if required. The intersection of the facility with the surrounding environment, community and other stakeholders addresses common questions such as 'Where does the water come from?', 'How much water comes from where?', and 'Where does the water go?'. Activities and uses of water internal to the operation include operational tasks (such as processing ore, dust suppression), water treatment and storing of water. It addresses common questions such as 'How much water do you recycle?', 'How much water do you reuse?', and 'How efficiently do you use water?'. The quality of the inputs and outputs addresses common questions such as 'What quality of water enters or leaves the site?' and 'How did an operation transform water quality?'.

Regardless of the level of detail to be included in specific water accounts, the concepts of materiality and context should apply to all accounting efforts. Information is material if its omission from the model can influence decisions related to the interpretation of the water account. For example, environmental water flows may be relatively small in volume, but may be critical for maintaining ecosystem health, and therefore should be included. A contextual statement is an essential part of the water accounting system as it ensures accounts are not divorced from the context in which a facility is operating. It should provide background information about the water resources of the operational facility as well as any conditions that have an impact on the management of those water resources

The accuracy of accounts is communicated through an accuracy statement, which shows the proportions of flows that are measured, estimated or simulated. Finally, notes provide information about major assumptions.

STATEMENT OF WATER INPUTS AND OUTPUTS

A Statement of Inputs and Outputs enables the consistent presentation of an operation water balance and it is based on the following key terms:

1. The operational facility is defined locally by the operation (or reporting/accounting entity) based on consultation with stakeholders, and alignment with other reporting requirements as necessary. It can include the total mining lease, or a smaller defined operational area. It must be spatially explicit, readily communicated and sensible.
2. An input is a volume of water, which is received by the operational facility, or has become available from within the operational facility (in the case of groundwater that was present before operations began, and has been subsequently accessed). Inputs can be summarized and aggregated by their sources or reported as a diversion.
3. Sources are the primary accounting description for inputs, they are described by the point of water extraction and include surfacewater, groundwater, sea water and third-party supply. Surfacewater is all water naturally open to the atmosphere, except for water from oceans, seas and estuaries. Examples of surfacewater include: water extracted from natural water bodies such as rivers, lakes, reservoirs, ponds, streams; rainfall and runoff collected from within the

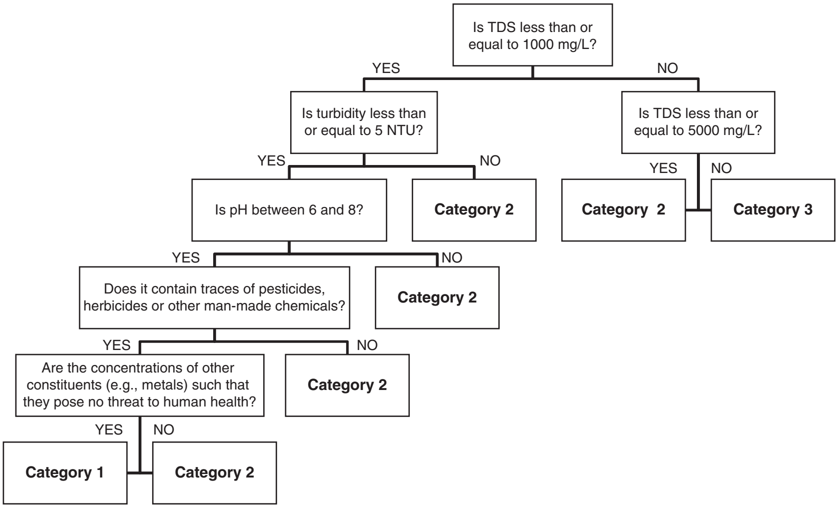
operational facility; precipitation that is captured directly by water storage facilities; and runoff collected from outside the operational facility.

4. Groundwater is water beneath the earth's surface that fills pores or cracks between porous media such as soil, rock, coal and sand, often forming aquifers. For accounting purposes, water that is entrained in the ore can be considered as groundwater. The volume of groundwater that is collected during the dewatering of ore bodies represents an input of groundwater and is reported as such.
5. Sea water is water from oceans, seas and estuaries.
6. Third-party supply is water provided by an entity external to the operational facility, usually through a commercial arrangement with specific infrastructure for water delivery. Third-party water contains water from the other three sources and, in some cases, the distribution of surfacewater, groundwater and sea water is known. However, minerals operations cannot be accountable for reporting the sourcing of water by third parties. If an operational facility has a commercial arrangement to receive water from a third-party entity, this water should be reported as third-party water. If a third party is acting as a facilitator to access water (for example, an operational facility is being granted access to a groundwater bore by the government or a neighbouring farm), the water should be reported as surfacewater, groundwater or sea water. When there is doubt, the physical source (that is, surfacewater, groundwater, sea water) should prevail.
7. Diversions include water that is diverted away from the operational facility, and is not involved in any of the tasks within the operational facility. It is water that is actively managed by the minerals operation, but is not used in a traditional 'consumptive' sense. Some handling losses can be incurred before the water is transferred to areas external to the operational facility. Examples of diversions include creek diversions, runoff diversions and aquifer dewatering with either subsequent groundwater reinjection or transfer to surfacewater external to the operational facility. The operation must be able to account through monitoring that the diverted water has arrived at the agreed destination.
8. An output is a volume of water that is removed from the operational facility.
9. Destinations are the primary accounting description for outputs; they are generally described by the point of water receipt outside the operational facility, and include surfacewater, groundwater, sea water, third-party supply, evaporation and entrainment (water removed

from the operational facility contained within product or waste streams). Water that seeps beneath storage or tailings storage facilities and is not recovered is reported as an output to the groundwater destination (usually under a seepage line item). An 'other' destination represents a combination of destinations and is used when a clear destination pathway cannot be identified.

WATER QUALITY DESCRIPTION

Under each source and destination water category, entries can be reported as being of a stated water quality, with three categories of water quality. Category 1 is water close to the standards of drinking water, as it only requires minimum treatment (disinfection) to be safe for human consumption. It can be used for all purposes. Category 2 is water that requires treatment to remove total dissolved solids (TDS) and to adjust other parameters to be safe for human consumption. It can be used for many agricultural and recreational purposes. Category 3 is saline water that cannot be used for any agricultural purposes without removal of total dissolved solids. The decision tree in Figure 5.2 can be used to help assign a water quality category to the inputs and outputs.



Note: NTU = nephelometric turbidity unit; TDS = total dissolved solids.

Figure 5.2 Selecting a water category for a water input or output

STATEMENT OF OPERATIONAL EFFICIENCIES

The objective of the reporting system is to provide a consistent methodology for quantifying and documenting water use within an operation, including its efficiency. The concept of water status (such as, raw, worked or treated) was developed, which describes whether or not water has been tasked and/or treated after it has entered the operational facility as an input. Raw water is received as an input and has not been previously tasked for any purpose by the operational facility. Stores are the facilities within the operational facility that hold and/or capture water. Tasks are operational activities that use water, typically ore extraction, ore processing, dust suppression, fire fighting and amenities uses. Worked water has been through a task and is returned to a store for the same or another future task. Worked water is characterized by the number of times it has gone through a task, which is labelled the cycle number. Treated water has been treated on-site to provide water of a suitable quality.[1]

All water, be it raw, worked or treated water can be tasked, treated or released as an output, thus the water status changes as it moves through the task–treat–store cycle. Acceptance of the status definitions enables the consistent development and application of the concepts of reuse and recycling. Reused water is worked water that is sent to a task without being treated. Reuse efficiency is the ratio of the sum of worked water flows to the tasks to the sum of all flows to the tasks. Recycled water is worked water that has been treated and is sent to a task. Recycling efficiency is the ratio of the sum of treated worked water flows to the tasks to the sum of all flows to the tasks.

PILOT PROJECT

The objectives of the pilot project were to:

1. map minerals industry water accounting definitions and concepts to the requirements of other frameworks;
2. explore the incorporation of water quality into the water accounting system;
3. update and refine the presentation of accounts, based on industry and other stakeholder feedback;
4. provide feedback to government agencies developing water accounting methods; and
5. undertake an accounting exercise across a region of mines and inform capacity-building requirements.

Five sites from the central New South Wales region participated in the pilot: two gold and copper mines, two copper mines and one coal mine. Four of the five sites were located within the Murray Darling Basin (MDB) and one site within a catchment that drained eastward. In terms of site maturity (that is, the stage that the mining and processing operations had reached within their life span), two sites were reaching the final stages of economically feasible ore grades, two sites were in the early stages of their mine life and one site had roughly exploited half of its economically viable ore grade stock. Whilst the main outcome of the project was a finalized version of mining industry water accounting, it is presented first for ease of discussion.

PILOT PROJECT RESULTS

The project methodology consisted of data collation, account generation and account testing, and identification of key reporting and disclosure issues and benchmarking opportunities. Generating an account requires a system representation of the site water network, calculation of values not measured (Cote and Moran 2009) and compiling contextual information.

Accounts were generated for each site and examples extracted from the results are provided in Tables 5.1, 5.2 and 5.3.[2]

To quantify the accuracy of the accounts, each flow was recorded as measured, calculated or estimated. The level of confidence associated with each of the flows was also assessed. An accuracy statement was then produced for each site.

Once accounts were available, they were used to analyse a site's strategic system planning and water use efficiency, communicate inter-site comparisons where suitable and to present indicators that could be used to benchmark water use. For four of the five study sites, the flows of water to the processing plant per ton of minerals processed could be compared (Table 5.4): total inflows into the processing task and raw water inflow into the processing task. These task-level indicators are useful as they allow a site to compare its water use efficiency in the main tasks with sites in similar situations.

Figure 5.3 shows site input from each source as a percentage of total site input and was produced using the input–output statements. These statements can be used by the mines to assess how they could improve their water management. For instance, Sites 1 and 3 have achieved low reliance on surfacewater and have diversified their water sources. Site 4, which has a high reliance on surfacewater, could investigate how they have achieved this.

Table 5.1 Example of Statement of Water Inputs and Outputs (1 July 2007 to 30 June 2008)

Inputs	ML	Quality
Surface water		
Precipitation and runoff	2535	Category 1
Rivers and creeks	1132	Category 1
Groundwater		
Aquifer interception	487	Category 2
Bore fields	354	Category 1
Entrainment	570	Category 2
Sea water	0	
Third-party water		
Town effluent	3800	Category 1
Entitlement transfer	418	Category 1
Total inputs	9296	
Outputs	**ML**	**Quality**
Surface water		
Environmental flows	319	Category 1
Groundwater		
Seepage	426	Category 2
Sea water	0	
Supply to third party	0	
Evaporation	4202	Category 1
Entrainment	3895	Category 2
Other – task losses	183	Category 2
Total outputs	9025	
Water balance		
Inputs – outputs (ML)		271
Storage at start (ML)		983
Storage at end (ML)		1254
Change of storage (ML)		271

Note: Input sources and output destinations are in italic; ML = megalitres.

Table 5.2 Example of Statement of Operational Efficiencies

Operational Efficiencies	
Total flows into tasks (water required to mine; ML)	41 522
Volume of reused water (ML)	32 520
Volume of water inputs to the operation (ML)	9 296
Reuse efficiency (%)	78
Volume of recycled water (ML)	24
Recycling efficiency (%)	0.06

Note: ML = megalitres.

Table 5.3 Example of an Accuracy Statement

Flow Types	Percentage of all Flows	Confidence (Per cent)		
		High	Medium	Low
Measured	50	50	0	0
Estimated	42	32	0	10
Calculated	7	0	0	7
Total		82	0	17

Table 5.4 Example of benchmarking task – water use

	Site 1	Site 2	Site 3	Site 4
Total inflow to processing ML/Mt	1.82	1.20	0.81	2.54
Raw inflow to processing m^3/ton	0.32	0.52	0.54	0.61

Note: ML/Mt = megalitres per megaton.

FUTURE APPLICATION

The vision is that the water accounting system developed for the mining industry will be voluntarily adopted to provide consistency for water accounting in the industry at the international and national level, and will inform the requirements of the other main water use reporting initiatives, as demonstrated below, particularly those of General Purpose Water Accounting. The main difference between the system presented here and the expectations laid out in General Purpose Water Accounting is that

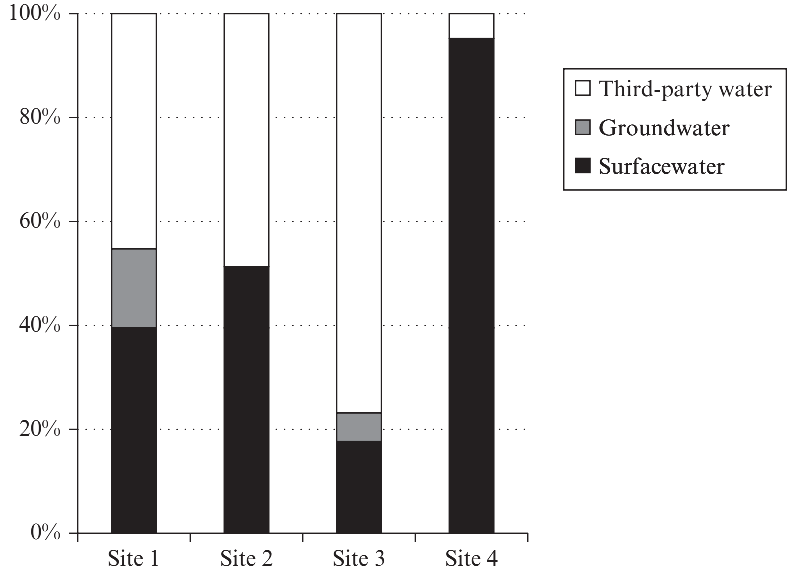


Figure 5.3 Input from each source as percentage of total site input

the former only considers physical flows of water. General Purpose Water Accounting on the other hand, includes the concepts of water assets and liabilities. Assets represent the total volume of water an operational facility will or can have access to, and water liabilities represent obligations to release water, whether they have already occurred or not. In most cases, determining water assets and liabilities of an operational facility will be done by combining information from the water accounting system about the reporting period water balance with that from contractual arrangements to obtain or deliver water. It is not anticipated that producing Statements of Assets and Liabilities will pose challenges. However, the concepts of water assets and liabilities are a new application of the broadly trusted concepts of financial assets and liabilities that mine site water resource managers are familiar with, where, for instance, a pipeline is an asset, but being obliged to repay debt on a loan that funded the pipeline construction is a liability. The new application of this concept to water resource management needs careful consideration, especially in the context of mine site water management, where it is not always the case that the more water the better. The specific situation of coal mines in Queensland, Australia provides a good example of such a situation. Recent regulatory changes prevent the release of mine water to the environment. Mines have been collecting and storing large volumes of water, which are posing management risks and are certainly not perceived as assets.

Regarding the GRI water indicators, the mining industry water input–output model provides all the information that is required to produce total water withdrawal by source and total water discharge by quality and destination. These performance indicators are specified in the GRI, namely EN8 and EN21 respectively. The GRI does not provide any guidance on how to derive the percentage and total volume of water recycled and reused (EN10). Analysis of EN10 shows that many sites include raw water in the reporting of water reuse (for example, runoff capture by process dams). Another major issue is that the definition of EN10 states that if 20 ML (megalitres) of water was recycled three times in a reporting period then 60 ML should be reported. This implies that an operation knows the cycle number of worked water, which is very unlikely. The requirement for calculation of the cycle number is yet to be identified by operations (Cote and Moran 2009). A major finding of Mudd (2008) was that there was inconsistency between the mines' interpretation of the indicators. The mining industry water accounting system provides clear guidance and instructions on how to obtain EN8, EN10 and EN21. Adoption of this water accounting system by mining firms will achieve consistency in GRI reporting and will strengthen confidence in the GRI indicators.

CONCLUSIONS

The mining industry water accounting system provides a solid platform with which to develop mine water accounts. It is based on a systems representation of a mining site, with detailed information about inputs, outputs, raw and worked water and options for characterizing essential features of an operational facility's water balance. It is intended that its primary users will be the operational facilities (mines, mineral processing operations), who will produce statements of: (1) physical flows (inputs, outputs), (2) water held in storage at the start and end of the reporting period, (3) water reuse, (4) accuracy with which those numbers were produced and (5) general context for the reporting period. This water accounting project is significant because in the last few years, many initiatives and tools have been developed to help business measure and report their water use and assess their water-related impacts. The mining industry water accounting system complements that of General Purpose Water Accounting. Adoption of the system by mining entities will avoid duplication of effort and contribute to strengthening the quality, transparency and comparability of water-related information to inform decision-making.

NOTES

1. Refer to Appendix 1 of DRET (2008) for more information regarding water treatment.
2. Complete example accounts can be found at www.wateraccounting.net.au; accessed 3 October 2011.

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6. Potential for the application of General Purpose Water Accounting in South Africa

Denis A. Hughes, Esther Corral and Nikite W.J. Muller

INTRODUCTION

The introduction of new approaches to managing water in South Africa (SA) followed the end of the apartheid government (Department of Water Affairs and Forestry (DWAF[1]) 1997; Republic of South Africa (RSA) 1998), removal of the concepts of riparian water rights and introduction of principles of equitable, sustainable and efficient access to water (DWAF, undated). The South African National Water Act (NWA) of 1998 introduced the concept that the only rights to water are for basic human need and the sustainability of the environment and that these rights should be preserved before water can be allocated to other users. However, as frequently pointed out (Biswas 2008; García 2008), the implementation of new water management policies can be a difficult task, particularly when the changes from previous practices are radical and not understood by everyone (van Wyk et al. 2006).

In the introduction to the National Water Resources Strategy (NWRS) in 2004, the South African Minister of Water Affairs and Forestry[2] acknowledged the importance of information by stating that, while SA apparently has enough water for the foreseeable future, data on which to reliably base this assessment are incomplete and inadequate. This apparent contradiction highlights the critical need for readily available information for water planning and management.

The overall responsibility for water management rests with the Minister of Water and Environment Affairs, through the Department of Water Affairs (DWA[3]). Part of the implementation of the NWA involves second and third tiers of management through the establishment of Catchment Management Agencies (CMAs – second tier) and Water User Associations (WUAs – third tier). Within these management structures, local and regional water boards, as well as municipalities, act as water service providers and are controlled under provisions within the Water Services Act (RSA 1997). The water boards and municipalities are responsible for the day-to-day management of potable water and wastewater treatment services in all urban (and many rural) areas of the country.

All of these management institutions need appropriate information to be able to operate effectively. This information needs to be compiled at a scale suited to the operational functions of the different institutions, should include the natural resource components and how they are utilized and should also cover issues of both water quantity and water quality. The information should be compiled and presented in a common standard format by all reporting entities and should be accessible and understandable to all stakeholders, including the general public, so that progress in implementation of the policies and principles of the NWA can be assessed. While some of the required information is currently collected it has generally not been integrated and compiled in a form that is accessible to stakeholders.

The Preliminary Australian Water Accounting Standard (2009) and its successor Exposure Draft Australian Water Accounting Standard (2009, 2010) articulate a comprehensive accrual-based reporting and management approach founded on the notion of general purpose financial accounting, which may satisfy the information, presentation and reporting requirements for the range of institutions responsible for the management of South African water resources.[4] A preliminary workshop (sponsored by the Water Research Commission of South Africa) was held in December 2009 to present the approach to a number of interested organizations, to discuss the advantages of the approach and to identify any potential shortcomings from a South African perspective.[5] This chapter summarizes the potential advantages of such a system and the critical issues that were raised during the discussions. In doing so, the chapter presents an example illustrating the constraints that might exist in implementing General Purpose Water Accounting within water management institutions in South Africa. The potential advantages of General Purpose Water Accounting over existing water accounting practices include the following:

1. A standard approach to water accounting that allows comparisons to be made between different catchments and allows information to be integrated within larger regions where there are a number of reporting entities.
2. Inclusion of all water assets and liabilities, including rights to water and obligations to deliver water, as well as identifying storage,

changes in storage and water fluxes in a transparent and understandable manner.
3. Inclusion of a provision for specifying the accuracy and quantification approach used for all the water assets and water liabilities and changes thereto, with the potential to highlight accuracy deficiencies, how these impact on the overall water balance and where additional monitoring efforts should be directed.
4. Ability to identify temporal variability in natural water availability and how this could impact on water users. It can also be used to assess the progressive implementation of water management policies and strategies and contribute to improved planning and management.

While the 2009 workshop identified that General Purpose Water Accounting has much to offer South African water management practice, several outstanding and interrelated informational and implementation issues need to be resolved before any serious efforts should be made to implement the system. These are listed below. The first three are discussed in this chapter, while the fourth is beyond the chapter's scope:

1. There are not presently sufficient and reliable information sources available to populate a water accounting system of the type proposed. This is illustrated in the application of General Purpose Water Accounting to the water balance components of the Amatole[6] water management system over a reporting period of one year.
2. General Purpose Water Accounting currently does not necessarily address water quality sufficiently. Water quality is one of the critical water resources management issues within South Africa and it is important that any water accounting system links quantities of water (in storage, or as fluxes) with quality indicators that relate to both environmental and human health and welfare.
3. It is unclear whether General Purpose Water Accounting can be applied across all spatial scales from the local, or single catchment scale, to the national scale given the lack of accuracy and resolution of the available data.
4. It is not clear at this stage how connections can be made between the volumetric and quality water accounts and various socioeconomic issues associated with water management. The latter may include the economic and social benefits derived from different water supplies, the capital and maintenance costs of physical infrastructure and the relationships with pricing policy.

APPLICATION OF GENERAL PURPOSE WATER ACCOUNTING TO THE AMATOLE REGION – BACKGROUND

The Amatole water management area comprises the catchments of the Buffalo (1287 km^2) and Nahoon (681 km^2) Rivers and the upper and middle reaches of the Kubusi River (592 km^2) and is situated in the semi-arid eastern Cape Province of South Africa (DWAF 2008). Water resources and water services are managed jointly by the DWA, Amatola[7] Water Board (AW) and Buffalo City Municipality (BCM). DWA manages some of the storage reservoirs and is responsible for operating river flow gauging stations, some of which are also water quality monitoring sites. AW is a not-for-profit organization with the members appointed by the government and is mainly responsible for water treatment and bulk water supply to BCM and some of the larger industrial concerns, while also managing several dams on behalf of DWA. BCM manages some of the storage reservoirs and is responsible for supplies to domestic and industrial users and for wastewater treatment.

There are eight major urban centres supplied by the Amatole water infrastructure: King William's Town, Bisho, Zwelitsha, Mdantsane, Berlin, Potsdam and East London within the Buffalo River catchment and Stutterheim in the Kubusi River catchment (Figure 6.1). There are

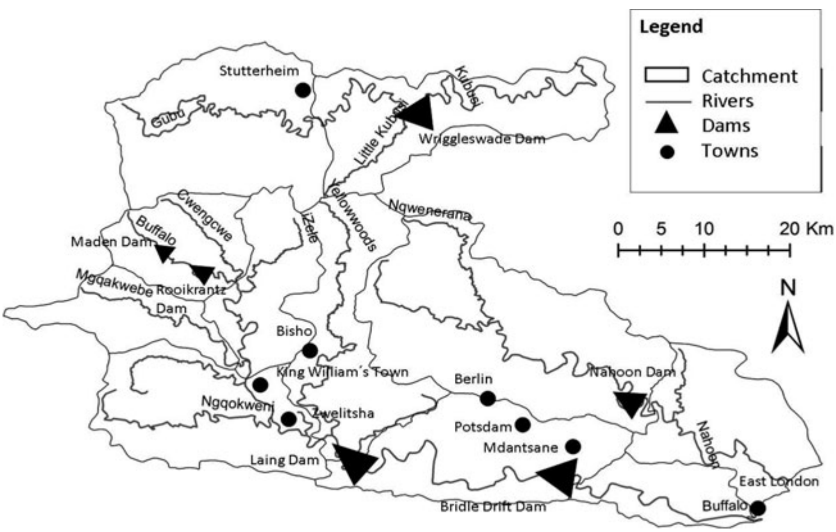


Figure 6.1 The Amatole system – location of major urban centres and reservoirs

Table 6.1 Capacity of reservoirs in the Amatole system

Zone	Reservoir	Owner/Operator	Capacity ($m^3 \times 10^6$)
Upper Buffalo	Maden	BCM/BCM	0.17
	Rooikrantz	DWA/AW	4.91
Middle Buffalo	Laing	DWA/AW	18.90
Lower Buffalo	Bridle Drift	BCM/BCM	101.57
Nahoon	Nahoon	DWA/AW	20.80
Middle Kubusi	Wriggleswade	DWA/AW	88.00

Note: BCM = Buffalo City Municipality, AW = Amatola Water Board, DWA = Department of Water Affairs.

also several rural towns and villages in the region. The major demand for water is domestic and industrial, with very little irrigated agriculture in the Buffalo River catchment. The area is an industrial and economic development hub within the eastern Cape Province and supports a growing population estimated to be approximately 770 000 in 2001 (BCM 2002; DWAF 2008). Some of the poorer urban centres (e.g., parts of Zwelitsha and Mdantsane) and rural areas are still experiencing water service delivery problems.

There are five water supply reservoirs within the main part of the system (Table 6.1 and Figure 6.1): Maden and Rooikrantz dams in the upper reaches of the Buffalo, Laing and Bridle Drift Dams in the middle and lower Buffalo and Nahoon Dam in the middle reaches of the Nahoon. Raw water from the neighbouring Kubusi River catchment can also be used to supplement storage in both Laing and Nahoon Dams, through releases from Wriggleswade Dam via a canal network into the Yellowwoods and Nahoon Rivers. While groundwater is used to a limited extent within the rural areas, the quality and yield from the underlying mudstones, shales and sandstones limit the value of this resource for large-scale bulk water supplies.

AW operates water treatment works for raw water abstracted from Rooikrantz and Laing dams and supplies bulk water to BCM as well as directly to some industry in King William's Town. In the hydrological year 2008 (October 2008 to September 2009), 32 per cent of BCMs bulk water was bought from AW with the remainder coming from its own water treatment works (Table 6.2). All of the wastewater treatment works are operated by BCM. Figure 6.2 illustrates that some of the wastewater treatment works discharge effluent upstream of water supply reservoirs, which, coupled with recent management and maintenance problems, contributes to water quality problems in both Laing and Bridle Drift Dams.

Table 6.2 Water treatment and wastewater treatment plants including the operator agency and the design capacity

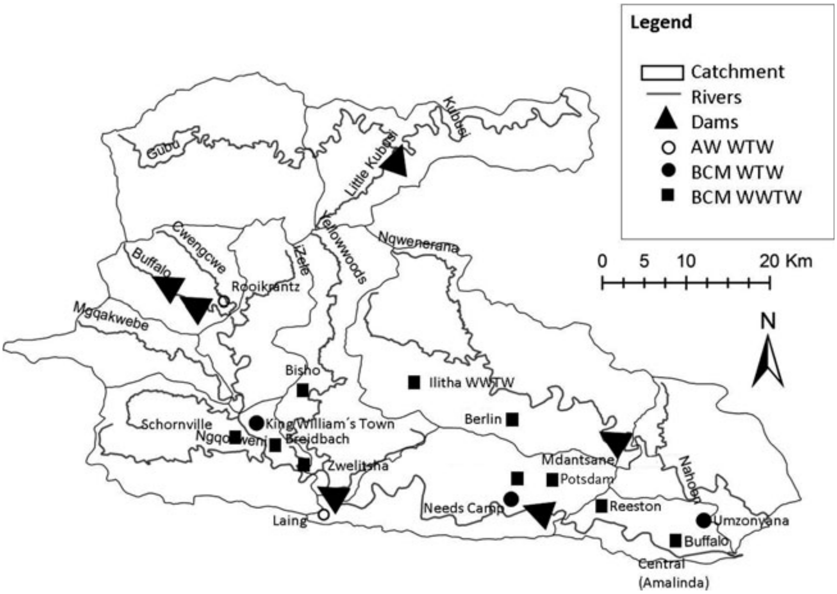
	Zone	Plant	Operator	Design Capacity ($m^3 \times 10^3 d^{-1}$)
Water treatment works	Upper Buffalo	Rooikrantz	AW	1.2
		King William's Town	BCM	12
	Middle Buffalo	Laing	AW	33
		Needs Camp	BCM	?
	Lower Buffalo	Umzonyana	BCM	24
Wastewater treatment works	Upper Buffalo	Schornville	BCM	5
		Zwelitsha	BCM	8
	Middle Buffalo	Bisho	BCM	1.5
		Breidbach	BCM	2
		Ilitha	BCM	?
	Lower Buffalo	Mdantsane/Potsdam	BCM	9
		Berlin	BCM	1
		Reeston	BCM	2.5
		Central (Amalinda)	BCM	5

Note: AW = Amatola Water Board, BCM = Buffalo City Municipality.

WATER BALANCE INFORMATION

This section is not intended to present the details of an application of General Purpose Water Accounting to the Amatole system, but to critically examine the availability and accuracy of the information that would be required for that purpose. The focus is therefore on the main requirements of General Purpose Water Accounting: the Statement of Water Assets and Liabilities, the Statement of Changes in Water Assets and Liabilities, the Statement of Physical Water Flows and the quantification approaches used for the magnitudes reported.

The main water balance components of the AW system are natural river flows, storage in reservoirs (raw water storage and treated water storage), evaporation losses from storage, abstractions for water treatment works and return flows from water treatment works. The natural river flow component could be further broken down into the components of the natural hydrological cycle (rainfall inputs; river flow, groundwater recharge and evapotranspiration outputs; soil moisture and groundwater storage changes). However, this would introduce



Note: AW = Amatola Water Board, BCM = Buffalo City Municipality, WTW = water treatment works, WWTM = wastewater treatment works.

Figure 6.2 Water treatment and wastewater treatment works in the Amatole system

additional uncertainties associated with quantifying these components. While abstraction from groundwater does occur, it represents a minor part of the overall system water balance. Storage in the natural channel system has been ignored as it is not measurable and is small compared to other components.

While rainfall and potential evaporation data are available from DWA for several sites within the region, there are insufficient gauging sites to accurately represent the true spatial variability, and attempts to represent these separate components of the natural hydrological cycle over a one-year reporting period would be very uncertain. There is also only a limited number of stream flow gauging stations that can provide information on the natural river flow component (Figure 6.3). The data for many of these stations are also affected by upstream reservoir releases, abstractions or return flows. During floods many of these gauging stations are not able to accurately record the flows, which could contribute to errors in the water balance during wet years. DWA also operates gauging stations on some

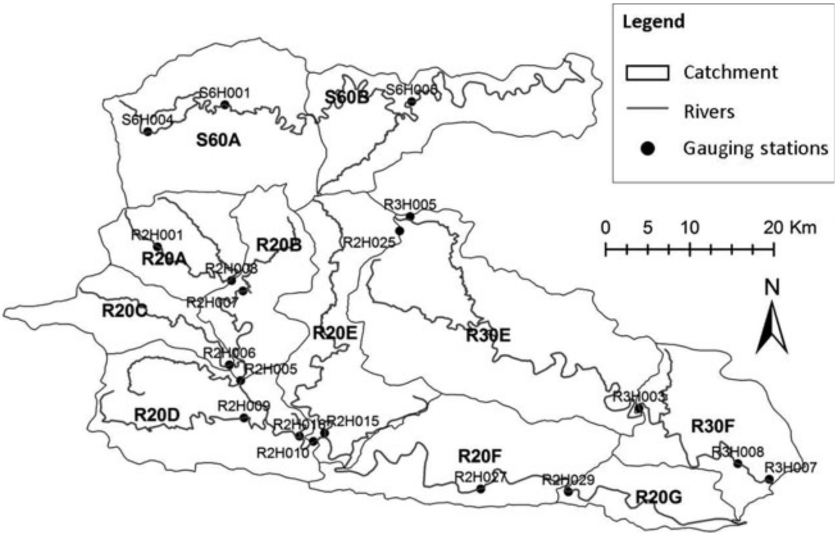


Figure 6.3 Stream flow gauging stations within the Amatole system

water transfer canals. The storage conditions within the main raw water supply reservoirs are readily available, but quantification of evaporation losses is based on assumed relationships between stored volume and surface area together with approximations of evaporative demand. These estimates will always be uncertain irrespective of the water system being used to report them. Future technological and methodological advances are likely to result in more refined estimations.

Downstream releases (to the river) from most of the storage reservoirs are gauged by DWA, while abstraction volumes to the water treatment works operated by AW are readily available. Unfortunately, these abstraction volumes are based on measurements taken at the treatment works and it is difficult to quantify the losses that occur within the distribution system. Some of these losses are expected to be quite substantial, given the age of some of the pipelines and the likely incidence of water theft. There is little information about the storage levels of the potable water storage reservoirs; however, this is likely to be a minor component and storage levels are unlikely to change significantly over a one-year reporting period. Information on abstraction and return flow volumes were not available from BCM due to administrative problems, a very serious impediment to completing any type of water account in the region. The lack of information about the operation of the main domestic and industrial supply reticulation system from BCM means that there are large gaps in the total water balance. Additional information is available about maximum reservoir storage capacities and the capacity of water transfer outlets from various government reports. While these gaps in the available data may have had little impact on day-to-day decision-making in recent years, they inevitably impact on the identification of trends in water availability and use and therefore on longer-term decision-making.

Table 6.3 illustrates the results of water balance calculations for two of the zones referred to in Table 6.1: the upper and middle Buffalo zones. Confidence levels of one (low) to five (high) are associated with all of the estimates and the calculated storage is based on Equation (6.1) and is used to estimate some unmeasured components so that the water balance could be closed.

$$\text{Calculated storage} = \Sigma \text{ Start storage} + \Sigma \text{ Inflows} - \Sigma \text{ Outflows} \quad (6.1)$$

Even for the relatively simple water balances shown in Table 6.3, which ignore several minor storage and flow components, it is apparent that the available information is uncertain. This is particularly true in the middle zone of the system where several tributaries contribute inflows to Laing Dam and one gauged tributary includes transfers from Wriggleswade Dam. Different levels of confidence are associated with the data from different sub-catchments. An item for 'other abstractions' has been included in the table to allow for direct run-of-river abstractions that are not accounted for in any of the other water balance components. However, information about these is currently not available. Perhaps the greatest concerns from an accounting point of view are the low confidence levels for the estimates of abstraction and wastewater treatment works return flows, as well as the lack of information about the fate of water in the main part of the urban reticulation system (that is, how much of the water abstracted for treatment actually reaches the consumers). In the absence of actual values, the wastewater treatment works volumes have been estimated to close the water balance and are much lower than the capacities and treated quantities reported for 2005 (DWAF 2008). However, some of the gauging station data used to estimate natural flows will include return flows from wastewater treatment works (for example, R2H011 on the Yellowwoods River and R2H010 and R2H027 on the Buffalo River). While it may be possible to close the water balance, the data given in Table 6.3 for the middle zone do not reflect the real sources of water, which will affect any assessments of the water quality that would be needed to inform decisions about improving the eutrophic status of the reservoirs.

One of the potential advantages of General Purpose Water Accounting

Table 6.3 Water balance for the upper and middle Buffalo River zones (October 2008 to September 2009)

Item	Start Storage	Inflows	Outflows	End Storage	Calculated Storage	Confidence Level
UPPER ZONE						
Storage and inflows						
Maden Dam	?			?		
Rooikranz Dam	3.92			2.84	2.84	5
Catchment runoff [1]		8.90				3 to 4
Rooikrantz outflows						
Total releases [2]			3.66			5
WTW abstractions			4.93			5
WTW abstraction losses [3]			1.20			2
Other abstractions			?			
Evaporation from storage			0.19			2
MIDDLE ZONE						
Storage and inflows						
Laing Dam	18.14			18.14	18.14	5
WWTW return flows[4]		1.88				1
Catchment runoff[5]		17.81				4
Laing outflows						
Total releases [6]			8.18			5
WTW abstractions			9.81			5
WTW abstraction losses [7]			1.47			1
Other abstractions			?			
Evaporation from storage			0.99			2

Notes: All values are in $m^3 \times 106$; WTW = water treatment works, WWTW = wastewater treatment works.

Confidence level: 1 = scaled from records at R2H012 (above Maden Dam), 2 = based on outflow records at R2R002, 3 = estimated to close the water balance: 24.3% of abstractions, 4 = estimated to close the water balance after the abstraction losses were estimated, 5 = scaled from several stream flow gauging records above Laing Dam, 6 = based on records at R2H027, and 7 = estimated to close the water balance: 15% of abstractions. While the water balance information for the lower zone (down to Bridle Drift Dam) are not provided, the data issues are very similar to those for the middle zone and the losses required to close the water balance were 20% of the wastewater treatment abstractions.

in this type of water management situation is that all of the responsible agencies (DWA, AW and BCM), as well as the consumers, would share the same accounting information, which would contribute to a common understanding of any water service problems. This shared understanding is sadly lacking in many local water management areas and leads to misunderstanding and a lack of trust. All major water supply schemes in South Africa are carefully planned by DWA through detailed modelling studies that are designed to estimate water demands and the sustainable yield of the system (DWAF 2008). Over the medium to long term, the implementation of a system such as General Purpose Water Accounting would allow operational designs to be assessed and updated. However, while the examples provided in Table 6.3 suggest that some information is readily available, the data have critical gaps that preclude the identification of different sources of water. In the case of the Amatole system it will be important to identify the water quality status of the different sources.

THE NEED TO INCLUDE WATER QUALITY

The Buffalo River catchment situation provides a good example of why measures of water quality need to be incorporated into the accounting system. Many of the wastewater treatment works in the catchment are upstream of the supply reservoirs, while ageing infrastructure, capacities that have not kept pace with expansions in water supplies and poor management of the treatment process have led to serious nutrient problems and frequent eutrophication of Laing and Bridle Drift Dams. This is not a unique situation in South Africa (DWA 2009) and serious water quality problems have been linked to non-compliance with wastewater treatment standards. Other quality issues are linked to matters such as mine drainage (heavy metals), faecal contamination resulting from storm water runoff from unserviced settlement areas, agricultural pollutants (herbicides, pesticides and nutrients) and industrial pollution (heavy metals and salts). Natural sources of water can also have variable water quality signatures and all of these can impact on the value and usefulness of water, or the costs of treatment to achieve potable standards. Although adequate quantities of water may therefore be available, the quality is either detrimental to aquatic ecosystem functioning, or may be hazardous to human health and welfare given the methods of purification that are currently available to most water service providers. Water accounts without indicators of water quality present an inadequate and incomplete picture of the available water resources and their fitness for use. On the other hand, an assessment that includes water quality indicators would be far more complete, could identify where mitigation actions are required, and could provide information about the effectiveness of any mitigation measures.

It is important to note that different water quality indicators may be appropriate to different uses of water and it is likely that a single integrated measure will not be sufficient. It will be necessary to consider separate indicators for dissolved salts, nutrients, heavy metals, microbiological condition and, in some regions, pesticides and herbicides. However, this means that quite substantial amounts of water quality data would need to be available. The National Water Act (RSA 1998) specifically states that the DWA has the responsibility to establish national systems that monitor, record, assess and disseminate information on water resources, and many of the stream flow gauging stations are also used as water quality monitoring points as part of the National Chemical Monitoring Programme. While the data are based on infrequent sampling (weekly or less frequent) there are approximately 1600 monitoring stations for which water quality (mainly inorganic chemistry) data are available, some with records extending back to about 1970. The aim is to provide information for water resource managers, scientists, decision-makers and the public on the surface inorganic chemical water quality of South Africa's water resources.

The National Eutrophication Monitoring Programme focuses on impoundments that exhibit high nutrient enrichment and eutrophication-related problems and measurements include total phosphate concentration and cyanobacterial pollution. The National Microbial Monitoring Programme provides information on the extent of faecal pollution in specific priority areas, and is designed to assess potential health risks. The most well-known component of the National Aquatic Ecosystem Health Monitoring Programme is the River Health Programme, which focuses on biological indicators (such as fish communities, riparian vegetation and aquatic invertebrate fauna) to evaluate the condition of river systems as a whole. Operating in selected catchments, the programme has other goals including the identification of spatial and temporal trends in the ecological state of aquatic ecosystems and the early detection of emerging problems.

In order to monitor the efficiency of water treatment works, DWA recently launched the 'Blue Drop' Certification system (DWA 2010). Based around national Drinking Water Quality standards, the Blue Drop campaign encourages local municipalities to improve their water quality monitoring and management efficiency. It also informs consumers about the quality of their supplied water. The 'Green Drop' certification system (DWA 2009) aims to improve the operational management of wastewater treatment works in order to reduce their negative impact on the water bodies into which they discharge. The most recent Green Drop report (ibid.) indicates that at least four of the wastewater treatment works operated by BCM do not comply with quality standards and have capacity problems.

The general conclusion is that if the various DWA water quality monitoring programmes are to continue to be effective there should be information available to inform a water quality component of a water accounting system. It is unlikely that the approach would need to be based on fully quantitative measures of different water quality components (for instance, detailed concentration data). It is more likely, however, that the approach should focus on an ordinal scale of fitness for use, differentiating between different consumer categories (domestic, industrial, agriculture and environment) based on several key water quality indicators.

SPATIAL SCALE ISSUES

For the application of General Purpose Water Accounting to be of value to South Africa it needs to support, and complement, existing approaches to water resources planning and management in South Africa. One of the main planning tools used by DWA is the reconciliation strategy studies (DWAF 2008) that are designed to quantify water resources availability (yield) and demand (including environmental water requirements) to provide information about future allocation strategies and the need for new water supply infrastructure (such as reservoir storage, inter-basin transfer schemes and alternative supplies using groundwater, desalination, and reuse) to meet demands into the future. These strategies are developed at the scale of river basins, which can be relatively small with few components (such as the Amatole system), or can be very large and highly complex (such as the Vaal system that includes many transfers from catchments outside the geographical limits of the Vaal River basin).

General Purpose Water Accounting appears to represent an extremely useful method of water accounting that can be used to assess the progress of implementation of water resources development plans and management strategies determined through reconciliation studies. These studies are designed to resolve conflicts between different water users and focus on yield, demands and assurance of supply, while the focus of General Purpose Water Accounting is on accounting for all storage, movement and use of water within the system on an annual basis. They are therefore, in principle, entirely complementary and to a large extent share similar information requirements. The main difference is that, to be successful, the accounting system requires more detailed and accurate information.

Given the assumption that reconciliation studies are repeated over time scales of several years to a decade (depending on the rate at which changes in demand occur), the detailed water accounts that are compiled between successive reconciliation studies would provide valuable information for planning future water allocations and infrastructure developments. The accounts would remove some of the uncertainties associated with determining yield and supply assurances in a country such as South Africa, where the temporal variability of climate and hydrology influence the accuracy of these estimations. Additional uncertainties at the planning level are associated with differences between actual water use and projected demand and losses within the system that are difficult to predict, but can substantially affect gross water consumption.

The integration of the information used for reconciliation planning and annual water accounting in systems such as the Amatole would be relatively straightforward, despite the limitations currently relating to the availability and accuracy of the available information. A limited number of report entities (DWA, AW and BCM) and a limited number of components (for example, storages, flow paths and liabilities) need to be included. Achieving the same integration objectives for much larger systems would be extremely difficult, but not impossible. The type of water resources system yield models (Basson et al. 1994) that are routinely used in South Africa for both planning and real-time operation are computer representations of the same type of information used for General Purpose Water Accounting, simulating storages and physical water flows (both natural and managed) over long time periods (± 70 years) to determine yields and to define optimum operating rules that will achieve certain objectives. System yield models have been established for the highly complex Vaal River system (DWAF 1996; Coleman et al. 2007) and it should be possible to achieve the equivalent water account.

A system as large as the Vaal would include a large number of report entities (namely, water boards, municipalities and DWA) and it is assumed that they would all compile water accounts for their part of the system. To achieve integration at the scale of the whole system means that these would all have to be brought together into a summary account that could be used to inform the planning process for the total system. The water accounting system would be comparable to financial accounting for a large corporate organization, whose individual divisions would compile detailed accounts, which would then be summarized for the organization as a whole.

Another issue is whether General Purpose Water Accounting is applicable at the national scale and if not, does this represent a fatal flaw with regard to its application in South Africa? The answer to this question lies in the fact that information about water resources at the national scale is not required for development planning and management; this is done at the basin scale (although often several basins are linked through transfer schemes). National scale information is required for more political purposes such as determining whether national service delivery targets are being met. If General Purpose Water Accounting is implemented at the basin scale, the preferred approach would be for the 19 CMAs in the country to be responsibile for synthesizing the water accounts generated for the report entities within their regions and provide the information required for a national report.

CONCLUSION

The conclusion of this initial assessment is that General Purpose Water Accounting represents a sound approach to water accounting for South Africa and that, with some reservations, it is practical to implement. This conclusion is founded in the advantages of standardization, transparency and the specification of uncertainties referred to in the introduction. The reservations are related to whether the water management entities compiling the accounts (or at least providing the information to an independent water accounting organization) have access to the necessary human and data resources. There are several problems with monitoring and publishing information in South Africa and not all public sector organizations consider these to be priority areas. Even though modelling and estimation methods can resolve some of these problems, gaps will persist in the required data and these will inevitably impact on the quality of the accounts. One of the advantages of General Purpose Water Accounting is that the critical deficiencies that exist in the current monitoring systems will be clearly identified.

It would be very easy to conclude that many areas of South Africa do not have the capacity to implement General Purpose Water Accounting and that we should not even try. However, a water-stressed country such as South Africa *must* implement some method of water accounting if it is to manage water resources effectively and in a sustainable and equitable way. The National Water Act (RSA 1998) clearly states that this is a national priority and the strategy should be to start implementing the approach in selected water supply systems, so that the necessary expertise and experience can be developed and gradually transferred to other areas. The sooner this process is started, the sooner the whole country will be covered by a standard approach to water accounting that will contribute to more effective and efficient management of water resources.

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NOTES

1. Note that during 2009 the Department of Water Affairs and Forestry (DWAF) became the Department of Water Affairs (DWA) and falls under the Ministry of Water and Environment Affairs.
2. See note 1.
3. See note 1.
4. For details of the General Purpose Water Accounting system, see www.bom.gov.au/water: accessed 1 October 2011.
5. The workshop discussed the Preliminary Australian Water Accounting Standard (PAWAS) released in May 2009 by Australia's Water Accounting Standards Board. As discussed in Chapter 1, in October 2010 the Water Accounting Standards Board issued an Exposure Draft of Australian Water Accounting Standard 1: Preparation and Presentation of General Purpose Water Accounting Reports (EDAWAS 1) that replaces the PAWAS.
6. The spellings Amatole and Amatola are both used in the region.
7. See note 6.

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7. Potential role of standardized water accounting in Spanish basins

Joaquín Andreu, Andrea Momblanch, Javier Paredes, Miguel Ángel Pérez and Abel Solera

INTRODUCTION

Many of the Mediterranean basins in Spain have a ratio of annual water demand to average natural renewable resource either close to, or exceeding one. A ratio higher than one indicates an overexploitation of natural reserves (such as aquifers) by recycling water and by recurrent importation of water from other basins. In water-scarce basins that are prone to intense and persistent droughts, this intensive use of water can lead to problems of low reliability of water supplies for non-priority uses (such as agriculture) and high risks of deficits for priority uses (such as urban supply) and for environmental flows.

Among the measures included in the Spanish basin plans to fulfil the European Water Framework Directive (WFD) (European Commission 2000) are new definitions of the regimes of ecological flows. This will require an augmentation of the water devoted to environmental protection and will reduce the water available for economic uses. In this context, measures to promote efficiency in water use are crucial for attaining the objectives of the WFD. Hence, greater rates of recovery of the costs of water services and water markets will also be promoted. It is expected that General Purpose Water Accounting could contribute to a better control of water in this new framework and also to greater transparency in the planning and management of water resources.

Water accounting for natural basins is not an easy task, as water balances cannot be more precise than the observations available. In Spain, the basins have automatic data-gathering systems, but the measurements may be insufficient and not sufficiently accurate to ensure a relevant and reliable reporting. Measurements of water flows are considerably less accurate than measurements of monetary flows. For instance, areal precipitation, evaporation and evapotranspiration (ET) represent significant amounts of water that must be estimated indirectly and underground flows can only be estimated by observations of piezometric levels and by modelling underground and surfacewater bodies jointly. This chapter summarizes methodologies currently used for obtaining information for water reports at different scales, focusing mainly at the basin scale, and the possibilities of linking them with a system such as General Purpose Water Accounting. It also reports an application of General Purpose Water Accounting to the Júcar Water Resources System (JWRS) in Eastern Spain, as well as suggestions to improve water accounting in water resources systems (WRS).

TOOLS USED FOR WATER INFORMATION REPORTING IN SPAIN

Basin authorities in Spain have databases provided by the Official Network Gauging Station and the Automatic Hydrological Information System and produce annual Exploitation Reports providing relevant information about water exploitation of basins. However, the reports do not provide a complete and standardized description of the state and operation of the system. The reports of Júcar Basin Authority (JBA)[1] contain information about precipitation, water assets and some flows at key points of the rivers (CHJ 2009). The reports also provide a full analysis for each management system in the basin, describing the flows diagram simplistically, the stored volume evolution, reservoir inflows and outflows and losses.

The National Statistical Institute (INE) prepares the Water Satellite Accounts in Spain (INE 2007). These accounts are statistical tools to evaluate the impacts to the aquatic environment of various economic activities. They contain four economic tables and five tables of water flows. These accounts follow the accounting adopted by Eurostat for the water environmental factor, the National Accounting Matrix including Water Accounts (NAMWA) (Van der Veeren et al. 2004) and advice from the System of Environmental-Economic Accounting for Water (SEEAW) (United Nations Statistics Division 2007). Both systems provide a framework for organizing physical and economic information related to water, consistently with the System of National Accounts (SNA) (United Nations, et al. 1993); however, the presentation of the information differs. This combination has led to the satellite accounts being adapted for application in Spain at the national and, in a simplified way, at regional and basin scales. The main applications for these accounts include calculating the water unit cost for each economic activity at a national level. Moreover, the adoption of an accepted methodology at the European level permits international data comparisons. Deficiencies identified in this reporting system include the lack of incorporation of natural water flows and corresponding balances; non-breakdown in agricultural categories, which means that 80 per cent of total consumption is represented in a single value; and incomplete information at the basin and regional scale.

TOOLS USED FOR WATER INFORMATION INTERNATIONALLY

Internationally, many tools for water accounting can be found with different objectives, scopes and contents. Some noteworthy examples are briefly described below.

The SEEAW (Vardon et al., Chapter 2 this volume) provides a framework for organizing physical and economic information related to water, consistently with the SNA. SEEAW accounts are organized in different groups: flows, assets, quality and resource valuation accounts, with the last two still under development. Its general objectives are to standardize water accounting concepts and methods and to integrate economic and physical data about water to provide indicators and statistical information for informed decision-making. This tool is suitable for reporting on the state and evolution of water resources. However, its structure and length make it difficult for the general public to understand. Further, the economic data needed for its compilation are difficult to obtain at the basin level, thereby compromising its usefulness.

The NAMWA, developed by Statistics Netherlands and quickly adopted by Eurostat, is a statistical information system that combines national accounts and water data in a simple matrix. This tool was designed to be applied at national scale. To increase its utility it was adapted to be functional at the basin scale between 2003 and 2004. NAMWA consists of ten economic accounts, two balance accounts and two emission accounts, providing information intended to evaluate water policy and water management, to identify economic and environmental indicators and to assist decision-making. The drawback of this tool is the unfriendly format of the information and the difficulty of obtaining economic data at the basin level.

The Water Accounting for Integrated Management of Water Resources is a methodology created by the International Water Management Institute (IWMI) (Molden 2009) to analyse water use, consumption and productivity in a basin. The tool was designed for the agricultural sector, but its structure is applicable to other sectors. It considers three scales: sub-basin, use and service. For all these scales, water balance components are calculated and classified by use and productivity, using terms consistent with hydrology. Indicators are then calculated for analytical purposes, namely the depleted fraction, process fraction and productivity of water. These indicators describe the present status and consequences of water resources-related actions carried out. The main objectives of this tool are to establish the terminology and procedures for describing the state of water resources and how they could be affected by water uses, identify opportunities for water savings or productivity gains and help in the decision process for resource allocation. This tool is similar to General Purpose Water Accounting (Slattery et al., Chapter 1 this volume) in the hydrological information presented and the format used, with a focus on obtaining some productivity index about water use.

The Colorado River Accounting and Water Use Reports, produced by the US Bureau of Reclamation (USBR 2008), are a group of tables reflecting changes produced in the river system by Arizona, California and Nevada users. This tool is specifically designed to meet Article V of the Judgment of the High Court of the US in the trial *Arizona* v. *California* (1964). The tables include a summary of the accounts, the stocks and the specifications of Article V. It is interesting that this is the only tool with monthly information.

The State of Environment third report of the Water Information System for Europe (WISE) (European Environment Agency 2009) provides information about available resources, withdrawals and water uses at the sub-basin scale. The objective of this report is to fulfil the commitment made by European Union Member States in the meeting of Strategic Coordination Group for the common implementation of the WFD in November 2009.

Finally, a practice related to water accounting is the concept of water footprint (Hoekstra et al. 2009). It is defined as the water volume consumed (or evaporated) and/or polluted required to produce goods and services consumed by a person, community or industry. It accounts for the water needed at all stages of the production chain to the consumer. Although its determination is relatively standardized, there is no single format to present data and its potential application in the field of a basin water management is low.

GENERAL PURPOSE WATER ACCOUNTING APPLIED TO THE JÚCAR WATER RESOURCES SYSTEM

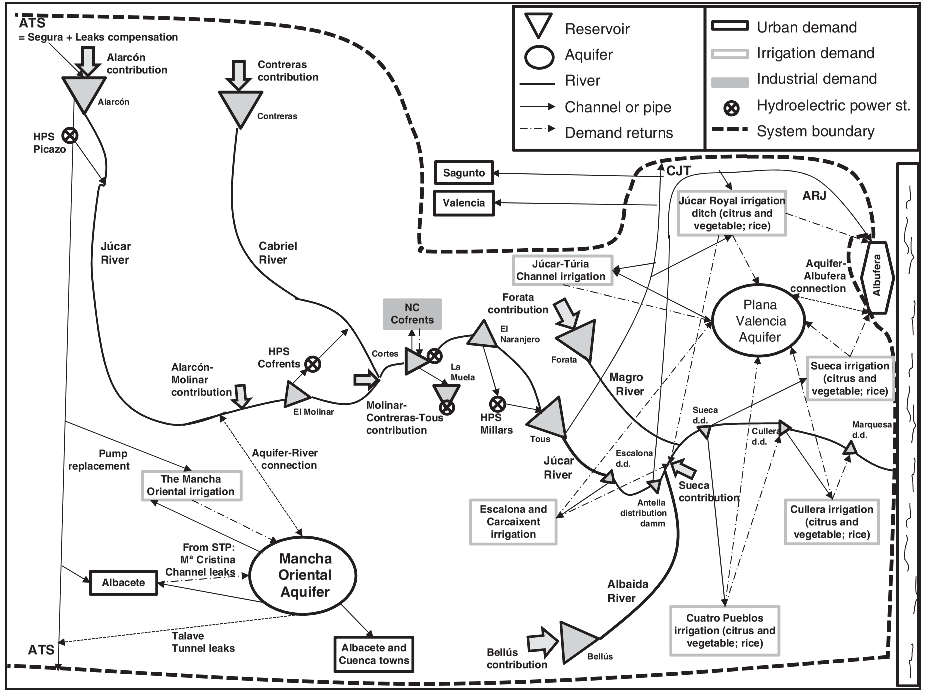
A great deal of information about JBA and JWRS can be found in CHJ (2005) and is available at the CHJ webpage (www.chj.es). Therefore, only the relevant information needed for contextualizing the chapter will be discussed. JWRS has an extension of 22378 km^2, with an average precipitation of 500 mm, and an average potential ET of 900 mm. There are 11 reservoirs with a total capacity of 2688 hm^3 (cubic hectametres). Average annual natural flows are 1182 hm^3/year. Water is mainly used for urban supply of Albacete, Valencia and Sagunto metropolitan areas (123 hm^3/year) and for irrigation. The rest of the urban supply, as well as some irrigated areas, relies on groundwater. Total water use for irrigation in 170000 hectares amounts to 995 hm^3/year. Hydropower generation is also present, as well as refrigeration of a nuclear plant. An additional complication is that the Alarcón reservoir in JWRS is used as an intermediate stage for a large transfer of water from the Tagus Basin to the Segura Basin. Also, the main aqueduct of this transfer is, in turn, utilized by some JWRS users as a conveyance facility for the surfacewater they get from the Júcar River. Aquifers play an important role as water reserves, base flow provision and source of supply, and interactions with surfacewater are very intense and complex. A simplified scheme of the JWRS is presented in Figure 7.1. The figure depicts the main relationships between the elements of the system and includes only the two more important aquifers of the exploitation system.

General Purpose Water Accounting (Water Accounting Standards Board, 2009) and the water accounting pilot projects in Australian subbasins (Bureau of Meteorology 2010) have been reviewed and applied to the JWRS.[2] Difficulties found in the implementation, as well as some proposals of improvement (Momblanch 2011), are described below.

General Purpose Water Accounting requires a description of the water reporting entity including its legal and climatic status. This information is available to be reported for the JWRS. The entity's physical description and administrative aspects, such as water plans, should be known by the report preparer. The information needed on climatic conditions during the reporting period can be obtained from the Exploitation Report published annually by the basin authority.

General Purpose Water Accounting is applied to a range of water report entities. Such entities include different water bodies and flows with differences in the order of magnitude. The precision of the estimates for the larger entities tend to be lower relative to that of smaller entities. Data on the JWRS, provided in Table 7.1, identify the assets in reservoirs and aquifers (as at 30 September) at 434.15 hm^3 and 10757.31 hm^3 respectively, while in rivers and the network transport, they are 2.91 hm^3 and 0.47 hm^3, respectively. The errors in the former can be larger than the total volume stored in the latter.

In order to estimate the precipitation, evaporation, infiltration to the soil, and water stored in the soil and in the aquifers, we have used the



Source: Momblanch (2011).

Figure 7.1 Simplified scheme of the Júcar Water Resources System (includes only the two more important aquifers for the exploitation system)

Table 7.1 Statement of Water Assets and Water Liabilities for the Júcar Water Resources System

Statement of Water Assets and Water Liabilities	2008 (hm^3)	2007 (hm^3)
WATER ASSETS		
1. Surface water assets		
1.1 Landscape water storage		
1.1.4 Soil moisture – unsaturated zone	285.90	248.81
1.2 Surface water storage – unregulated		
1.2.1 Unregulated river channel storage	0.39	0.39
1.2.3 Unregulated major storages (>1 hm^3)	4.56	4.38
1.3 Surface water storage – regulated		
1.3.1 Regulated river channel storage	2.91	2.91
1.3.3 Regulated major storages (>1 hm^3)	434.15	317.69
1.3.4 Regulated minor storages (<1 hm^3)	1.76	1.76
1.4 Water transport system storage		
1.4.1 Distribution network carrier storage	0.47	0.47
1.4.2 Within distribution network storage	0.10	0.10
TOTAL SURFACE WATER ASSETS	730.24	576.51
2. Groundwater assets		
2.1 Groundwater storages		
2.1.1 Unconfined aquifer	10 027.07	10 040.45
TOTAL GROUNDWATER ASSETS	10 027.07	10 040.45
3. Other water assets		
3.2 Other water assets		
3.2.1 Other water assets	0	0
TOTAL OTHER WATER ASSETS	0	0
TOTAL WATER ASSETS	10 757.31	10 616.96
LIABILITIES		
5. Other water liabilities		
5.2 Other water liabilities		
5.2.1 Other water liabilities	0	0
TOTAL LIABILITIES	0	0
6. Net water assets		
Opening net water assets (2)	10 616.96	10 489.73
Change in net water assets (3) = (1) − (2)	140.35	127.23
CLOSING NET WATER ASSETS = TOTAL WATER ASSETS − TOTAL LIABILITIES (1)	10 757.31	10 616.96

maps from PATRICAL, a precipitation-runoff model integrated with water quality (Pérez 2005). This model provides distributed values for all the variables of the hydrological cycle using a grid of cells of 1 km by 1 km. The estimates for the hydrological year from 1 October 2007 to 30 September 2008 in the area of JWRS (excluding the headwaters of the main reservoirs) are a total precipitation of 7659.07 hm^3, an infiltration of 6448.83 hm^3, an ET of 6435.92 hm^3 and an unsaturated soil asset of 285.90 hm^3.

Some of the General Purpose Water Accounting reports need modification to accommodate Spain's water management and specifically that in the JWRS. For instance, the water liabilities in the Statement of Water Assets and Water Liabilities have been simplified because water entitlements cannot be carried over in Spain like they can in Australia. The allocated water that is not supplied in the reporting period is considered part of the available resources for the next period. Therefore, the allocation and the supply to demands are not coincident due to changes in the management, or in the meteorology. Consequently, the term 'allocation adjustments' contains the difference between the allocation and the supply. This adjustment has been added with the opposite sign because the supply can be higher than the allocation.

Some terms appear to be missing in the chart of accounts used in the methods pilot for implementing General Purpose Water Accounting. For example, precipitation into the different elements does not include explicitly the rainfall into the transport system. This volume should be introduced in the accounting, as the transport system is considered in the storages appearing in the Statement of Water Assets and Water Liabilities. Another common term in the Statement of Changes in Water Assets and Liabilities and the Statement of Physical Flows is the return from demands. Surface returns do not include industrial returns, but they should be introduced because the industrial allocation and diversion are present in the accounting. In the JWRS application, the estimates of returns from water users through different ways (surface and groundwater) have been obtained from Aquatool, a decision support system (DSS) for water resource management simulation (Andreu et al. 1996) used by JBA. Also, it is necessary to change or clarify the nomenclature used for runoff in the General Purpose Water Accounting Reports, because General Purpose Water Accounting uses unregulated runoff and regulated runoff to name contributions to rivers and reservoirs, respectively. These terms are confusing given that they are not in tune with the meaning of regulated/unregulated used in the Statement of Water Assets and Water Liabilities. In the latter account, they represent the existence of storage and flow controls in a water body.

The environmental requirements in the JWRS have been treated similarly to demands. They are established in the water basin plans (CHJ 1998) and are subordinated only to urban demands. The estimation of the assets that guarantee the environmental uses is complex, because the operation of the system to satisfy the demands is often enough to maintain minimum

Table 7.2 Balancing items for General Purpose Water Accounting pilot cases and the Júcar Water Resources System (hm^3)

	Balancing Item S2	Allocation to Demands	% Error S2	Total Water Assets	% Error S2
Namoi-Peel	3310.18	138.80	2384.92	14768.93	22.41
Murrumbidgee	5796.09	1191.32	486.53	78314.78	7.40
Murray-Darling	122443.09	3474.01	3524.54	1052040.31	11.64
Onkaparinga	30.38	6.28	483.82	149.62	20.30
Júcar WRS	384.35	1140.01	33.72	10757.31	3.57
	Balancing Item S3	**Diversion to Demands**	**% Error S3**	**Total Water Assets**	**% Error S3**
Namoi-Peel	3310.18	86.77	3815.11	14786.93	22.39
Murrumbidgee	5796.09	815.21	710.99	78314.78	7.40
Murray-Darling	122895.47	2982.57	4120.45	1052040.31	11.68
Onkaparinga	30.38	6.28	483.82	149.62	20.30
Júcar WRS	384.35	967.15	39.74	10757.31	3.57

Note: S2 = Statement of Changes in Water Assets and Water Liabilities; S3 = Statement of Physical Flows.

flows. Otherwise, in drought periods, demand supplies are minimized and it is necessary to release water from reservoirs with environmental purposes exclusively. Thus, the environmental allocation is the volume necessary to fully satisfy the environmental requirements (75.69 hm^3), while the volumes actually diverted are the ones released for environmental purposes; these are determined by comparing the releases downstream of the reservoirs with the demand needs.

In General Purpose Water Accounting, the statement of water assets and water liabilities contains estimations of the system assets, which are relatively easy to measure with reliability. However, the other statements contain varied flows that entail higher errors. In order to evaluate the quality of the values introduced in the Statement of Changes in Water Assets and Liabilities and the Statement of Physical Flows, balancing items are calculated. Table 7.2 reports the balancing items obtained for the JWRS and for the pilot cases reported by the Bureau of Meteorology in Australia, accompanied by the percentage that they represent for total allocations to demands in the Statement of Changes in Water Assets and Liabilities, or supplies to demands in the Statement of Physical Flows. This is meaningful, since a water report entity is interested in the relative errors regarding the volumes it really manages to satisfy users' needs. For the JWRS, these balancing items are 384.35 hm^3 in both the Statement of Changes in Water

Assets and Liabilities and the Statement of Physical Flows (33.72 per cent of the sum of surface and groundwater allocations and 39.74 per cent of the sum of surface and groundwater supplies). These balancing items coincide given that these accounts differ only in the concepts relating to demands, and the term 'Adjustments in allocations', in the Statement of Changes in Water Assets and Liabilities, corrects the estimation errors. In the pilot cases, the balancing items range between 486.53 per cent and 3524.54 per cent of the sum of surface and groundwater allocations in the Statement of Changes in Water Assets and Liabilities, and between 710.99 per cent and 4120.45 per cent of the sum of surface and groundwater supplies in the Statement of Physical Flows. These errors are unbearable from a hydrologist's or a basin authority's point of view, and we believe that the main sources of errors causing the imbalance are the estimates of hydrological variables that cannot be directly measured in extensive areas, such as precipitation, evaporation and ET, and also the surface–groundwater relationships. This could be due to a lack of data (spatial density of observations), lack of accuracy or poor representation of reality by the models used to estimate these variables. When the balancing items are high, General Purpose Water Accounting could be a good tool to evaluate the source of error and show improvement of the accounting balance. However, even though the JWRS, PATRICAL and Aquatool models are quite well calibrated for hydrological standards, the accuracy of the results suggests that the balancing item is too significant for General Purpose Water Accounting to contribute to clarifying and controlling water assets and flows.

REFLECTIONS: OBJECTIVES OF WATER ACCOUNTING, THE SCALES OF THE REPORTS AND THE DOMAIN OF THE ACCOUNTING

In Spain, and hence in JWRS, water planning and management at the basin level has traditionally been handled by user-participated basin authorities. Currently, decisions on water allocations are based on quite sophisticated analysis of the water resource systems, using models and standardized reliability indicators to assess the performance of the system under different planning horizons and scenarios (Andreu et al. 2009a, 2009b). Also there is a tradition of public annual reports of relevant figures about storage, supplies and flows in the basin. However, these reports are not standardized across the different Spanish basins. Therefore, General Purpose Water Accounting could be a useful tool for better control of water use and water efficiency in the context of water scarcity and of technical and economical efficiency objectives. In addition, water accounting should be implemented at different scales and by most of the water entities related to different water uses. The methodologies should ensure the feasibility of coherent up-scaling and/or downscaling of the figures. This practice will also contribute to a greater transparency in the planning and management of water resources and in the potential water markets that would be expected in the new framework, with better information for the public and stakeholders.

The findings associated with the application of General Purpose Water Accounting in Spain, and also from our experience in water management at the basin authority scale, suggest that General Purpose Water Accounting may not contribute to the initial objectives of the system. The analysis displays a high level of uncertainty in the estimates of terms that account for a huge proportion of the assets and/or fluxes. If these data are publically available, rather than clarifying issues, the results may generate greater confusion. It would be difficult to understand, from a public point of view, large 'errors', giving a wrong impression that they might be due to mismanagement, when the fact is that they are due to oversizing of the reporting domain.

The application of General Purpose Water Accounting to an irrigation district, 'Acequia Real del Júcar' (ARJ) (depicted as Júcar Royal Irrigation ditch in Figure 7.1), is also considered. There are approximately 35 000 farmers (the average size of farms in eastern Spain is very small) within the 20 000 ha of the ARJ. ARJ receives water from JWRS through a recently constructed modern pipe and distribution system with automatic devices to control water flows and deliveries to farms, which are undergoing a transformation to efficient pressurized drip irrigation systems. ARJ can also receive water from an aquifer beneath the region (Plana de Valencia aquifer shown in Figure 7.1) during periods of drought. Applying General Purpose Water Accounting to this irrigation district would be relatively easy and produce reliable information if limited to the conveyance, storage and distribution system. The measurements related to storages in the ARJ's small reservoirs, flows in the canals and pipes and supplies to the farmers, have a high degree of accuracy with an almost negligible balancing term. If the reporting extended to include all the water fluxes and storages in the ARJ's territory and beneath (that is, the hydrological cycle), although it could give an impression of full accounting of water, the information would be less reliable. Measurement inaccuracy increases for items requiring indirect measurement such as precipitation, infiltration, ET, soil moisture storage, deep percolation and groundwater flows. Including such information in water reports may not necessarily improve decision-making related to water use and control as the information may convey a poorly controlled system, when the reality is quite the contrary.

The applicability of General Purpose Water Accounting to a basin authority, such as the JBA managing the JWRS, is also addressed. There is a branch of the JBA, the Exploitation Area, which has the control of public infrastructures in the basin and which also controls the Automatic Data Gathering System of the agency. If the Exploitation Area of the JBA adopted General Purpose Water Accounting restricted to information about reservoir storages and flows related to the management of the entity, the reports could be prepared relatively easily and with small balancing items, thereby providing reliable and relevant information on surfacewater use and control in the system. However, extending the water accounting to capture the physical frontier of the basin, including all elements participating in the hydrological cycle as well as the data provided by lower-scale reporting entities (such as the ARJ and the Exploitation Area), would introduce estimates with less precision and may create an impression of a poorly controlled system, when the reality is quite the contrary.

The analysis presented suggests that General Purpose Water Accounting in Spain can provide useful information for decision-making. However, its application should be restricted to items that can be measured accurately and should minimize estimations. There is no point applying detailed General Purpose Water Accounting to items that belong to the hydrological cycle and that can be summarized by observations of flows in some key points. For instance, the result of all accounting in the headwaters of a reservoir (such as Alarcón) can be summarized by the inflows to the reservoir, which can be better estimated, for a given hydrological year, by a balance in the reservoir. So the recommendation is to reduce the domain of the accounting to a point to which a minimum of the concepts require indirect estimates. This would result in the terrain, aquifers and hydrological cycle of the headwaters not being included in detail, but rather summarized by the inflows to the reservoirs. In contrast, the area where the aquifer of Mancha Oriental is located, with a surface of 7280 km^2, could be fully represented, since it is subject to very intense exploitation (about 400 hm^3/year of pumping), it is monitored by many observation piezometers and wells and by a remote sensing program in order to estimate vegetation variables and distributed groundwater models are available for its simulation.

Given the above discussion, General Purpose Water Accounting has been applied to the Exploitation Area domain plus the aquifer of Mancha Oriental and the aquifer of Plana de Valencia Sur. The assets considered are only reservoirs and the mentioned aquifers and the flows included are those that the water report entity, in this case the Exploitation Area of JBA, controls or manages in any manner. As can be seen in Table 7.3, the results of this new approach that introduces into the water accounting

Table 7.3 General Purpose Water Accounting balancing items for the Júcar Basin Authority Exploitation Area (hm^3)

	Balancing Item S2	Allocation to Demands	% Error S2	Total Water Assets	% Error S2
JBA Exploitation Area	−116.27	1140.01	10.20	5770.83	2.01
	Balancing Item S3	**Diversion to Demands**	**% Error S3**	**Total Water Assets**	**% Error S3**
JBA Exploitation Area	−116.27	967.15	12.02	5770.83	2.01

Note: S2 = Statement of Changes in Water Assets and Water Liabilities; S3 = Statement of Physical Flows.

only the terms accurately known by the water report entity, corroborate that this method improves the reliability of data and the GPWA report only contains the information relevant to the water entity's users. Now the balancing items are only 10.20 per cent of the sum of surface and groundwater allocations in the Statement of Changes in Water Assets and Water Liabilities and 12.02 per cent of the sum of surface and groundwater supplies in the Statement of Physical Flows. As compared to the total water assets, the balancing terms are now 2.01 per cent in the statements.

CONCLUSIONS

General Purpose Water Accounting has been applied to the JWRS and the benefits and the difficulties of its application highlighted. It can be concluded that General Purpose Water Accounting could be a powerful tool to improve transparency of water management when economic uses and environmental needs coexist. However, in the effort to be rigorous and with the aim to be useful at all scales using the same structure, the system includes concepts that can be difficult to estimate at certain scales, thereby threatening the accuracy of the accounting as reflected in large balancing terms or in a relatively high degree of uncertainty. Further, some water report entities do not have the capacity to implement General Purpose Water Accounting, due to the lack of available data (Hughes et al., Chapter 6 in this book). This implies a big effort would be required by water report entities to develop systems to capture the information for reporting. To facilitate its implementation, water accounting needs a hierarchy of institutions making water accounting into the same domain, allowing the smallest ones to feed on the bigger. Some of these difficulties will have to be solved before water accounting can be satisfactorily applied to an entire water reporting system or river basin.

One approach has been developed to address these difficulties. The approach involves reducing the domain of General Purpose Water Accounting initially to the physical domain where storages and flows are well measured or estimated. This approach recognizes the need to find equilibrium between maximizing the representation of the elements in the basin and the accuracy and rigour of the accounting. In addition, it will be necessary to continually improve measurement devices; knowledge about the characteristics and behaviour of complex elements, such as aquifers; and knowledge of the interactions between elements of the water reporting system and the models used to indirectly estimate some of the variables, in order to maximize the usefulness of the information provided.

Finally, if the balancing items were small, General Purpose Water Accounting could improve transparency, assess an entity's management and assist coordination between water entities. It could also assist in avoiding conflicts between riparian territories, as is justified in Chapter 13 of this book (Allan). However, inferences about alternative policies cannot be captured just by monitoring, and therefore adequate and integrated modelling of the alternatives is needed to predict their impacts.

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NOTES

1. The JBA is a public agency whose functions are developing and implementing the River Basin Plans, managing public water, and designing, building and operating water infrastructure in its territory. The council of JBA (or CHJ in Spanish) includes national, regional and local government representatives, as well as users and stakeholder representatives.
2. The application of General Purpose Water Accounting to the JWRS was premised on reviewing the Preliminary Australian Water Accounting Standard (PAWAS) released in May 2009. As discussed in Chapter 1, an Exposure Draft of Australian Water Accounting Standard 1: Preparation and Presentation of General Purpose Water Accounting Reports (ED AWAS 1) was issued in October 2010 replacing PAWAS.

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8. Development and application of the System of Environmental-Economic Accounting for Water in China

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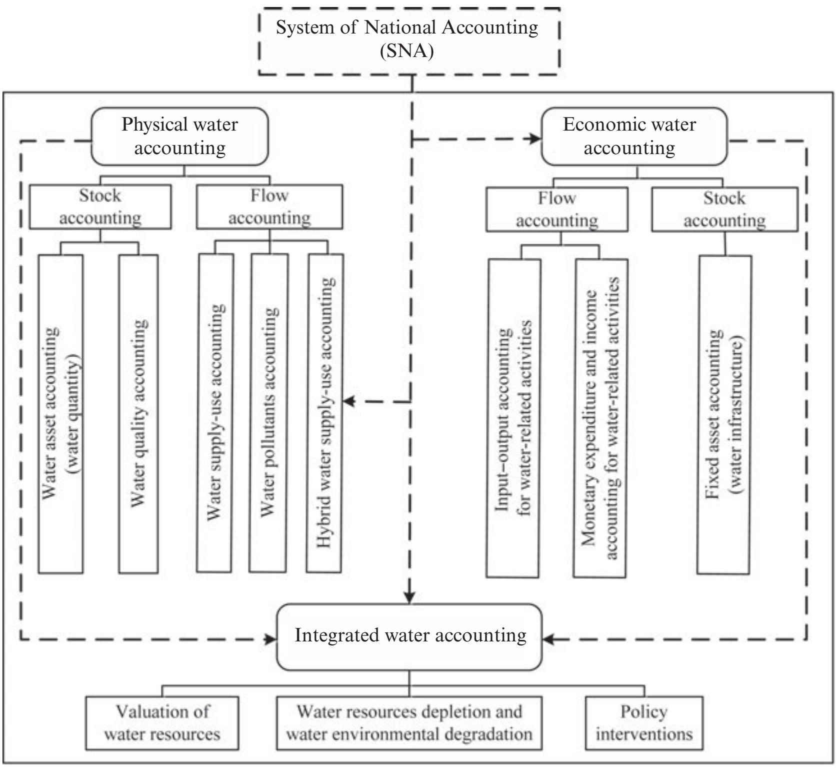
INTRODUCTION

The China Water Accounting Project was initiated in November 2006 by the Chinese Ministry of Water Resources (MWR) with assistance from the National Bureau of Statistics (NBS) and the United Nations Statistics Division (UNSD). Its purpose is to establish a water accounting framework based on international experiences and standards, with the primary objective of supporting water resources management. The MWR and NBS modelled the Chinese Water Accounting Framework on the System of Environment-Economic Accounting for Water (SEEAW), with adaptations to suit the Chinese environment. Both theoretical and applied research were conducted to inform the development of what is now a preliminary water accounting framework, and physical and economic accounts have been prepared at the national level and for four regions: the Beijing and Shanghai municipalities and the Haihe River and Taihu Lake basins. In addition, based on these accounts, case studies have been undertaken on the valuation of water resources, the cost of resource depletion and environmental degradation, and policy interventions. The development of water accounting is playing an important role in strengthening water resources management in China and in particular enables the construction of a range of indicators that can be used by decision-makers. This chapter outlines the application of SEEAW in China, how it aligns with or differs from the UNSD's framework and approaches and its application in the future.

STRUCTURE OF THE CHINESE WATER ACCOUNTING FRAMEWORK

Water accounting in China involves the integration of economic and hydrological data and reports the data in ways designed to support water resource management. The objectives and principles of the Chinese Water Accounting Framework (CWAF) are consistent with those of SEEAW (United Nations Statistics Division 2007). The CWAF SEEAW comprises three components (shown in Figure 8.1): physical water accounting, economic water accounting and integrated water accounting.

Physical water accounting describes the total amounts, in physical terms, of water existing as surfacewater, groundwater (such as in aquifers) and in soils, and their variation over a certain time period (for



Source: Gan et al. (2009).

Figure 8.1 Components of the Chinese Water Accounting Framework example, a year). It describes both stocks and flows of water. Stocks of water resources are measured in terms of both their water quality and quantity (or volume), indicating how people affect the environment by abstracting water and discharging wastewater. The flows are described in terms of the amounts of water abstracted, supplied, used, consumed and discharged. The pollutants discharged in the water are also estimated. By reporting both volumes and quality of water stocks and flows, physical water accounting shows the impact on the water cycle on social and economic activities.

Economic water accounting is designed for all water-related activities and includes both physical and economic data that are organized according to the existing economic accounting principles of the System of National Accounts (SNA). Economic water accounting consists of two parts:

1. accounting for input–output of water-related industries, taking water-related industries with the development, management and protection of water resources as a special case of economic activities; and
2. accounting for financing, expenditure and capital assets information for the purpose of development, management and protection of water sources activities.

Based on physical water accounting and economic water accounting, integrated accounting evaluates the relationships between water resources and the national economy. It enables the valuation of water resources, costing of water resources depletion and water environmental degradation, and studies of likely impacts of policy interventions. This can provide information for policy recommendations on, for example, the development and management of water resources, financing of water supply infrastructure and the location of industrial development.

PROGRESS TO DATE

In the three years since the commencement of the CWAF, substantial progress has been made, including the production of several of the SEEAW standard tables, or variations thereof. The tables are a water asset account, physical supply and use tables, emission accounts, a hybrid account for supply and use of water and water quality accounts.

The most developed of these accounts are the physical supply and use tables and the water asset account, which is described in the next section. Limitations of the basic data have meant that the economic components of the accounts, and in particular the hybrid accounts, are still at an early stage of development and lack some of the data required to populate them. Notwithstanding these issues, the asset account, emissions, hybrid and water quality accounts are presented and discussed in this chapter.

For the emission accounts, water quality accounts and economic accounts in the SEEAW standard proposed by UNSD are open for adjustment and have been modified to make them China specific. Extending SEEAW, attempts have been made in the CWAF SEEAW to incorporate the valuation of water resources and the value of water resource depletion and environmental degradation. The outcomes of these attempts are also discussed in this chapter.

WATER ASSET ACCOUNTS

Asset accounts describe the stocks of water resources at the beginning and end of an accounting period and the changes in stocks that have occurred during that period (SEEAW). Accordingly, the scope of water assets is extensive, including all water bodies (such as surfacewater, groundwater and soil water), but excluding sea water and atmospheric moisture.

Based on current techniques, it is difficult and not necessary to know how much water assets exist as stock in lakes, rivers, ground, soil, glaciers, and so on, at a specific point of time. The opening stock in the account is not shown and the closing stock is simply presented as the relative change to the opening stock (that is, increases in stocks minus decreases in stocks). Fundamentally, this means that the water asset account is not representative of the stock of water assets but rather the change in them during the period.

The 2005 water asset account for China is shown in Table 8.1. The stock of water assets increased by 53.3 billion m^3. The stock of surfacewater decreased by 57.5 billion m^3, groundwater stock increased by 240 million m^3 and soil water stock increased by 110.5 billion m^3. Abstraction by human activities (for example, irrigation, water supply, entertainment) is 561 billion m^3, representing a relatively small effect on total decreases in water stocks.

EMISSIONS WATER ACCOUNTS

Emissions water accounts record the amount of pollution added to water by industry and households. Unfortunately, data for the primary industries (for example, agriculture) were incomplete or unavailable at the

Table 8.1 China's 2005 water asset account

		Surfacewater	Soil Water	Groundwater	Total
1 Opening stocks	0	N/A	N/A	N/A	N/A
Increases in stocks	1	2921.70	4144.17	866.78	7932.66
2 Returns	2	204.42	–	57.67	262.09
3 Precipitation	3	2039.33	4061.63	–	6100.96
4 Inflow	4	677.96	82.54	809.11	1569.61
4.a From upstream territories	5	19.05	–	N/A	19.05
4.b From other resources in the territory	6	658.91	82.54	809.11	1550.57
Decreases in stocks	7	2979.16	4033.67	845.34	7858.16
5 Abstraction	8	457.23	–	103.88	561.11
6 Evaporation/Actual evapotranspiration	9	135.04	3267.68	–	3402.72
7 Outflow	10	2386.89	765.99	741.45	3894.33
7.a To downstream territories	11	683.28	–	N/A	683.28
7.b To the sea	12	1660.49	–	–	1660.49
7.c To other resources in the territory	13	43.12	765.99	741.45	1550.57
7.d Water transfer	14	N/A	–	–	N/A
8 Other changes in volume	15	N/A	N/A	21.21	21.21
9 Closing stocks	16	−57.46	110.50	0.24	53.28

Note: – = nil or unimportant; N/A = not available; measurement: billions cubic metres.

Source: Gan et al. (2009).

time these pilot emission water accounts were prepared and hence are not included in them.

Emissions water accounts have been prepared for several pollutants and Table 8.2 presents the emission accounts for chemical oxygen demand (COD) and for ammoniacal nitrogen (NH-N) for 2005. This information is important for evaluating water quality. The total discharge of COD from point sources (cities and towns compared with rural areas) in China was 17.59 million tonnes and that of ammoniacal nitrogen was 1.70 million tonnes. The discharge of pollutants from urban households and from industries (including the service industries) was approximately equal, with the discharge of COD from urban households accounting for 51.1 per cent of the national total, while for ammoniacal nitrogen it was 52.0 per cent.

The total net discharge and discharge to rivers of COD from point sources in 2005 was 14.14 million tonnes and 11.94 million tonnes, respectively. The net discharge and discharge to rivers of COD from urban households sources accounted for 46.5 per cent of the national totals. The net discharge and discharge to rivers of ammoniacal nitrogen were 1.498 million tonnes and 1.024 million tonnes, respectively, and those from urban household sources accounted for 49.6 per cent of the national totals.

HYBRID WATER ACCOUNT FOR SUPPLY AND USE OF WATER

Hybrid accounts for the supply and use of water combine monetary values and physical quantities of water in the same table to enable, among other things, the economic benefits of water use by industries to be described. Using hybrid accounts permits the analysis of possible trade-offs between alternative water policies and economic strategies (SEEAW). Importantly, the information provided in the hybrid account allows the derivation of indicators for evaluating the impacts of change in the economy on water resources and thus provides a database for the study of economic issues related to water.

The hybrid water account for China (depicted in Table 8.3) includes the volume and values of the flows of water within the economy but does not include data on fixed capital formation or value of total assets for water supply and sanitation, as these monetary data are not yet available. Unsurprisingly the accounts show that the electricity, gas and water supply industry produces 91.9 per cent or USD13.3 billion of the value of water supplied. It also shows that small amounts of water were produced by the mining and manufacturing industries (USD0.5 billion). Water

Table 8.2 China's 2005 emission water accounts for COD and NH-N

	Industry (by Industrial Classification for National Economic Activities, GB/T 4754 – 2002)						Urban Households	Grand Total
	Primary industry	Secondary industry			Tertiary industry	Total		
		Subtotal	Mining & manufacturing	Electricity, gas & water				
Pollutant COD								
1. Gross emissions	N/A	5842	5658	185	2769	8611	8982	17593
1.a Direct emissions to water	N/A	5430	5258	172	908	6338	2946	9284
1.a.1 Without treatment	N/A	2144	2035	109	908	3052	2946	5998
1.a.2 After on-site treatment	N/A	3286	3224	63	0	3286	0	3286
1.a.3 To water resources	N/A	5172	5009	163	518	5690	1679	7369
1.a.4 To the sea	N/A	258	250	8	391	648	1267	1916
1.b To sewerage	N/A	412	399	13	1861	2273	6036	8309
2. Reallocation of emission by sewage treatment plant	N/A	117	114	4	1117	1234	3623	4857
3. Net emissions	N/A	5547	5372	175	2025	7572	6569	14142
4. To the rivers	N/A	4683	4535	148	1710	6392	5546	11938

Table 8.2 (continued)

	Industry (by Industrial Classification for National Economic Activities, GB/T 4754 – 2002)						Urban Households	Grand Total
	Primary industry	Secondary industry			Tertiary industry	Total		
		Subtotal	Mining & manufacturing	Electricity, gas & water				
Pollutant NH-N								
1. Gross emissions	N/A	542	533	9	272	814	882	1 695
1.a Direct emissions to water	N/A	504	496	8	89	593	289	882
1.a.1 Without treatment	N/A	280	272	8	89	369	289	658
1.a.2 After on-site treatment	N/A	224	224	0	0	224	0	224
1.a.3 To water resources	N/A	480	472	8	51	531	165	695
1.a.4 To the sea	N/A	24	24	0	38	62	124	187
1.b To sewerage	N/A	38	38	1	183	221	592	813
2. Reallocation of emission by sewage treatment plant	N/A	21	21	0	140	161	454	616
3. Net emissions	N/A	525	517	8	229	754	744	1 498
4. To the rivers	N/A	359	353	6	157	516	508	1 024

Note: N/A = not available.

Source: Gan et al. (2009).

represented USD13.8 billion or 0.2 per cent of total economic output in 2005. The value-added by the electricity, gas and water supply industry was USD102.6 billion or 4 per cent of total industry value-added. It should be noted that industry value-added is an identity of the SNA found by adding wages and salaries to profits by this industry. As such, it captures both costs and revenue associated with the production and sale of electricity and gas, but these are not able to be disaggregated for publication at this stage.

A range of indicators can be constructed from the hybrid accounts. For example, Figure 8.2 shows water use per unit of value-added by industry in China in 2005. The overall water use per USD1000 of value-added was 181 m^3, in which farming, forestry, animal husbandry and fishery had the highest value of 1587.4 m^3 per 10 000 yuan, while the tertiary (or service) industries had the smallest at 7 m^3. For water consumption, the amount per USD1000 of value-added was 95 m^3, of which farming, forestry, animal husbandry and fishery and the tertiary industries still had the largest and smallest values, respectively. These figures indicate how efficiently water is used in various economic sectors and can be compared with other regions or countries when the monetary unit remains consistent.

WATER QUALITY ACCOUNTS

Water quality accounts describe the quality of water stocks and how the quality changes over time. Water quality is assessed according to five classes of quality, with Class I being the best quality and Class V the poorest quality. Water assigned to any of Class I–III is suitable for human consumption (potable water). The water quality in China is evaluated according to quality standards issued by the Ministry of Water Resources, Ministry of Housing and Urban-Rural Development and Ministry of Environmental Protection. These standards relate to water function zones[1] in terms of use functions of water bodies such as rivers, lakes, or reservoir storage and groundwater. In order to facilitate water resources protection and management, separate water quality accounts are prepared for rivers, lakes and reservoirs.

Rivers

In 2005, of the river water evaluated for quality, 5.1 per cent was Class I, 28.7 per cent Class II, 27.1 per cent Class III, 11.8 per cent Class IV, 6.0 per cent Class V and 21.3 per cent was of a quality poorer than Class V. There was little change in the percentage of water assigned to each class between 2004 and 2005 (refer to Figure 8.3).

Table 8.3 China's 2005 hybrid water account for the supply and use of water

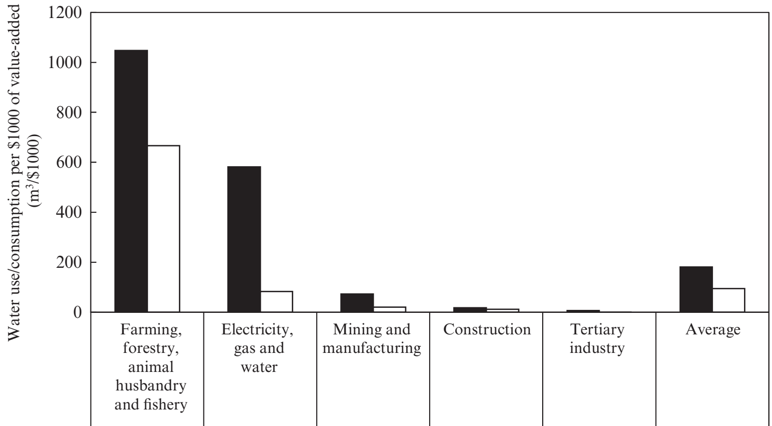
	Intermediate Consumption of Industries				
	Primary industry	Secondary industry			
		Subtotal	Electricity, gas & water	Mining & Manufacturing	Construction
1. Total output and supply (10^9 USD)	597.74	5428.20	325.14	4497.85	605.21
Of which: tap water production and supply	0.00	13.77	13.30	0.48	0.00
Treatment and recycle of wastewater	0.00	0.85	0.77	0.08	0.00
2. Total intermediate consumption and use (10^9 USD)	247.20	4069.98	222.58	3396.95	450.45
Of which: Tap water production and supply	0.18	6.92	1.23	5.18	0.52
Treatment and recycle of wastewater	0.02	0.45	0.06	0.36	0.03
3. Total value-added (gross) (= 1−2) (10^9 USD)	350.55	1358.21	102.56	1100.89	154.76
4. Total use of water (billions cubic metres)	367.26	207.31	123.8	80.74	2.77
4.a Abstraction from environment	110.58	106.49	62.02	43.67	0.8
4.b Use of water received from other economic units	256.69	100.82	61.78	37.07	1.97
Of which:Tap water production and supply	0	11.6	0.75	9.29	1.56
From hydraulic engineering	256.14	70.28	42.35	27.51	0.41
Treatment and recycle of wastewater	0.54	0.27	0	0.27	0
Wastewater	0	18.68	18.68	0	0
5. Total supply of water (billions cubic metres)	133.67	175.49	116.1	58.51	0.89
5.a Supply of water to other economic units	0	34.66	30.43	3.85	0.38
Of which: To other units	0	30.43	30.43	0	0
To sewage treatment plant	0	4.23	0	3.85	0.38
5.b Total returns	133.67	140.83	85.67	54.66	0.5
5.b.1 To surfacewater	87.27	108.74	60.08	48.29	0.37
5.b.2 To groundwater	46.4	8.25	4.15	3.96	0.14
5.b.2 To the sea			21.44	2.41	
6. Total (gross) emissions of COD (thousands of tonnes)	0	5842	185	5658	0

Note: USD1.0 = 6.6 RMB.

Source: System of Environmental-Economic Accounting for Water in China (Gan et al. 2009).

Table 8.3 (continued)

Intermediate Consumption of Industries		Actual Final consumption		Capital Formation	Rest of the World	Others	Total
Tertiary industries	Total	Household	Government				
2183.53	8209.47				899.98		9109.45
0.00	13.77				0.00		13.77
0.00	0.85				0.00		0.85
1066.82	5383.98	1079.06	403.11	1221.91	1037.80	−16.68	9109.20
3.94	11.05	2.64	0.00			0.11	13.77
0.23	0.68	0.15	0.00			0.00	0.85
1116.71	2825.48						
352.03	926.6	43.4			0	9.19	979.19
345.9	562.96	20.67			0	2.3	585.93
6.13	363.64	22.73			0	6.89	393.26
5.01	16.6	12.39			0	0.35	29.34
1.12	327.54	10.34			0	6.27	344.16
0	0.82	0			0	0.27	1.09
0	18.68	0			0	0	18.68
349.92	659.08	19.94			0	3.2	682.22
347.86	382.52	10.73			0	0	393.26
344.16	374.58	0			0	0	374.58
3.71	7.94	10.73			0	0	18.68
2.05	276.56	9.21			0	3.2	288.96
0.9	196.91	4.77			0	2.74	204.42
0.39	55.04	2.17			0	0.46	57.67
0.77	24.61	2.26			0		26.87
2769	8611	8982			0	0	17593

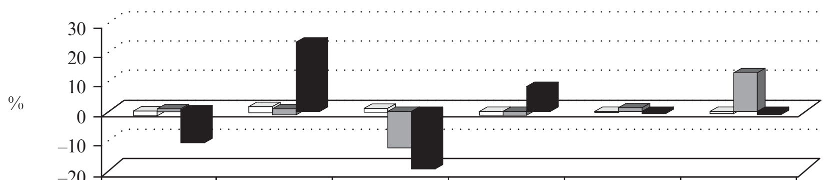


	Farming, forestry, animal husbandry and fishery	Electricity, gas and water	Mining and manufacturing	Construction	Tertiary industry	Average
■ Water use	1047.7	581.9	73.3	17.9	7.0	181.4
□ Water consumption	666.4	83.5	20.2	12.1	1.9	95.0

Note: USD1.0 = 6.6 RMB.

Source: Gan et al. (2009).

Figure 8.2 Average 2005 water use/consumption per unit of value-added



	Class I	Class II	Class III	Class IV	Class V	Poorer than Class V
□ River	–1.2	1.5	1.2	–1	0	–0.5
■ Lake	0.3	–0.3	–12.8	–1.4	1.3	12.8
■ Reservoir	–10.7	23.3	–19.1	8	–0.8	–0.6

Source: Gan et al. (2009).

Figure 8.3 Variation of river, lake and reservoir water quality between 2004 and 2005

Lakes

A total of 48 lakes in China were evaluated for water quality in 2005. The evaluation revealed the following: Class I water quality accounted for 0.9 per cent of the total stock, Class II accounted for 41.3 per cent, Class III accounted for 13.5 per cent, Class IV represented 8.9 per cent, Class V accounted for 3.9 per cent and water of poorer quality than Class V comprised 31.5 per cent. Figure 8.3 reports the changes in the percentage of water assigned to each class between 2004 and 2005. Compared with 2004, the percentage of stocks of Classes III and V changed significantly, with that of Class III decreasing by 12.8 per cent, stocks of Class V increasing by 12.8 per cent, and stocks of Classes I to III (that is, potable water) decreasing by 12.8 per cent.

Artificial Reservoirs

An evaluation of water quality was also undertaken for 320 of China's reservoirs in 2005. The results show the percentage of water stocks in categories Class I–V as 4.7 per cent, 64.7 per cent, 11.6 per cent, 13.2 per cent and 1.7 per cent respectively. The percentage of water in storage of a quality poorer than Class V was 4.1 per cent. As depicted in Figure 8.3, compared with 2004, the percentages of stocks of Classes I and III decreased by 10.7 per cent and 19.1 per cent, respectively, while those of Classes II and IV increased by 23.3 per cent and 8.0 per cent, respectively. Potable water decreased by 6.5 per cent.

SUB-NATIONAL ACCOUNTS

In addition to the trial accounts that have been compiled at the national level, accounts have also been prepared for the Haihe River and Taihu Lake basins and Beijing and Shanghai municipalities. Table 8.4 illustrates the water accounts prepared in China as part of the pilot program.

ESTIMATING COSTS ASSOCIATED WITH THE USE AND DEGRADATION OF WATER RESOURCES

A theme underlying integrated environmental-economic accounting is to include natural resources as an integral part of the national economic accounting framework. This facilitates a more comprehensive evaluation of the contribution to, and impacts on, the national economy from

Table 8.4 Water accounts prepared in China at the national and sub-national level as part of the China Water Accounting Project

Contents	National Level	Haihe River Basin	Taihu Lake Basin	Beijing	Shanghai
Asset accounts	●	●	●	●	
Stocks of river					●
Water quality accounts	●	●	●	●	●
Physical water supply and use tables	●	●	●	●	●
Emission accounts	●	●	●	●	●
Hybrid account for supply and use of water	●	●	●	●	●
Economic accounts	❍			❍	

Note: ● = finished; ❍ = partly finished.

natural resources use. Accordingly, a range of adjustments to the SNA has been proposed. This range includes, for example, green GDP and depletion-adjusted GDP. At present there is no international consensus on the preferred adjustments to GDP. Indeed the SEEAW clearly states 'the SEEAW does not discuss the calculation of macroeconomic aggregates adjusted for depletion and degradation costs' (United Nations Statistics Division, 2007, p. 26).

Per capita water resources in China are only about 25 per cent of the world average level (as measured by total annual renewable resources per capita) with large areas of China facing critical levels of water stress (World Water Assessment Program 2009). Despite water scarcity, water prices are lower than cost in many areas of China. This intensifies the need to attempt the economic valuation of water resources via the methods developed by resources and environmental economics and incorporate them into China's water accounts.

Currently, there is little focus in China on the cost of providing water to users or the price paid by the users. By assigning values to water, policy-relevant information can be produced to facilitate decision-making such as:

1. providing recommendations to water authorities on the development and management of water resources in water pricing decisions;
2. providing technical support regarding valuation to decision-makers on rate setting of water abstraction fees, waste discharge fees and water prices;

Table 8.5 Value of water depletion of China in 2005

River Basins	Water Depletion (Billions Cubic Metres)	Cost of Water Depletion (Thousand USD)	Proportion of GDP (%)
National	24.8	22 894	0.82
Songhuajiang	3.0	2 773	2.00
Liaohe	1.4	1 288	0.92
Haihe	10.4	9 591	2.46
Huanghe	3.9	3 621	1.71
Huaihe	3.4	3 182	0.74
Yangtze	0.7	652	0.07
Southeast River	0.1	61	0.04
Pearl	0.7	636	0.15
Southwest River	0.0	0	0.00
Northwest River	1.2	1 091	1.81

Note: USD1.0 = 6.6 RMB.

Source: Gan et al. (2009).

3. providing recommendations to government on investment in water supply and water pollution control;
4. setting up macro-level indicators; and
5. providing recommendations on governmental policies on industrial development.

The Value of Water Resource Depletion

In China, as in many countries of the world, water is deliberately supplied to industries and households at a non-market price, reflecting its public good nature, due to its critical importance for human survival, its importance to industry for production and the lack of a competitive water market. As such there is no true market price for water.

However, shadow prices for water may be derived by combining the data in the water accounts with additional data and the application of input–output methods or linear programming models. The details of the methods are beyond the scope of this chapter but the processes for deriving values for water resources from the data in China's water accounts appear in Table 8.5. The table indicates that the value of water resources depletion in 2005 was USD 22 894 000, representing 0.8 per cent of GDP in that year. By region, the value of water resources depletion as a percentage of GDP was highest in the Haihe River region (2.5 per cent) and lowest (zero) in the Southwest Rivers region.

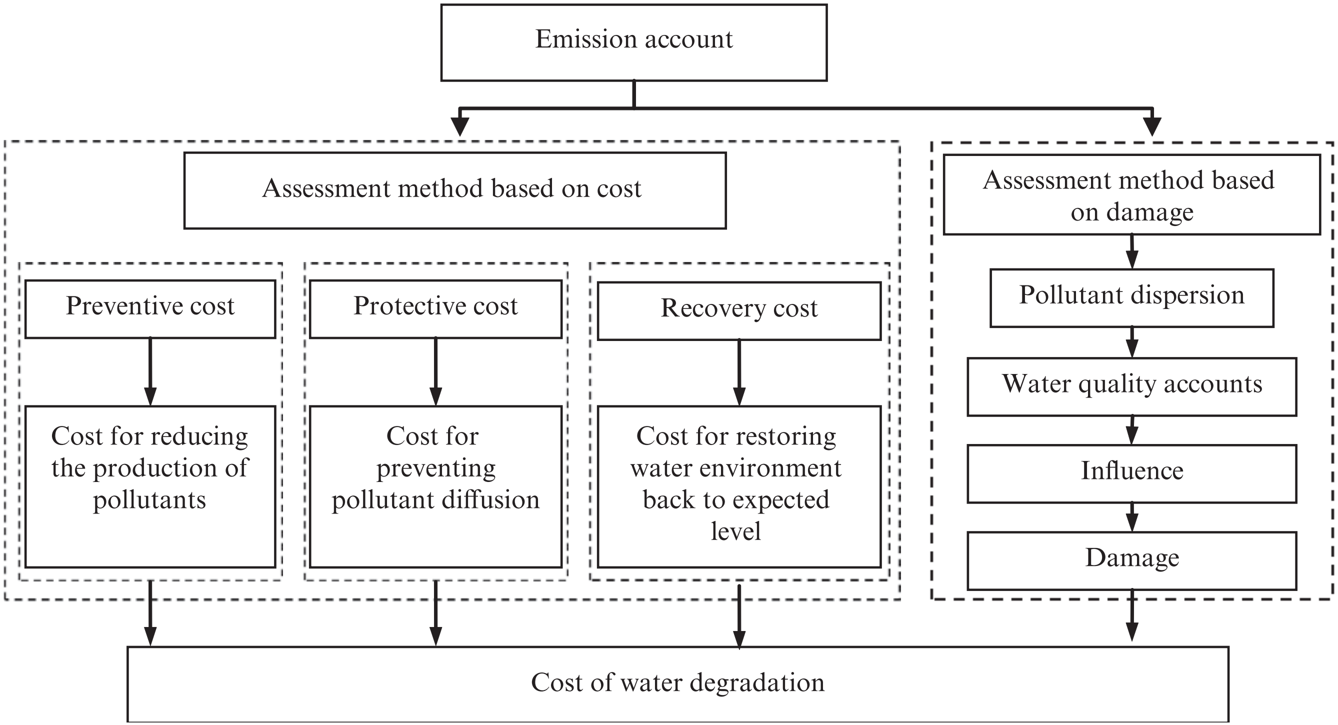
Value of Water Degradation Caused by Emissions from Industry and Households

The value of the degradation of water refers to the reduction of the value of water resources resulting from decreases in water quality and the resultant limitation on the use of water for particular economic activities. At present it is impossible to make an accurate estimation for all of the services that water provides. However, it is possible to compare the use of water (without a true market value) with economic goods and services that have a market value to estimate the degree of damage to the pollution assimilation function of water caused by pollutant discharge from the economy in excess of the assimilation capacity. This estimate can then be incorporated into the analysis of economic and social impacts on water quality and also in any cost/benefit analyses undertaken by governments and others of options for investment in water infrastructure projects.

In China, work on valuing degradation of water has begun and some preliminary estimates have been prepared. Only the main concepts and broad methods used are presented here. There are two approaches to estimating the value of environmental degradation. The first is cost-based (using preventive, protective or recovery cost). The second approach is damage-based, and equates pollution-caused economic loss with the cost of environmental degradation, under the assumption that no protective and remedy measures are adopted (Gao et al. 2007). The conceptualization for the valuation of water degradation in China is shown in Figure 8.4. The cost-based methods focus on the application of cost parameters of water pollutant treatment and purification techniques, whereas the damage-based methods rely more on water quality models and relevant technical parameters. Because of the different costing principles, there is a significant difference in the outcomes from applying the two approaches. Generally, the cost-based methods produce smaller valuations compared with the damage-based methods.

USES OF THE WATER ACCOUNTS: ESTABLISHING THE STATISTICAL INDICATOR SYSTEM OF WATER RESOURCES

China's water accounts have been used in establishing a statistical indicator system and a process to enable the regular publication of data



Source: Gan et al. *(2009)*.

Figure 8.4 Conceptualization of water degradation valuation method on natural resources and the environment. The process involved interdepartmental collaboration between the National Bureau of Statistics, Ministry of Water Resources, Ministry of Land and Resources, Ministry of Environmental Protection, Ministry of Housing and Urban-Rural Development and Ministry of Industry and Information Technology. In this process six working groups were established to develop indicators for energy, water, land, forestry, discharge of pollutants and investment in pollution abatement and control.

Using this process and the SEEAW, as well as the experiences of other countries, a preliminary statistical indicator system for water resources was developed, which includes 20 indicators in four categories, as shown in Table 8.6 (Working Group of Statistical Indicator System for Water Resources 2009)[2]. The indicators cover economic, environmental and social aspects of water and many are derived directly from the water accounts.

Improving the Coherence and Integrity of Water-Related Statistical Data

In China, there are a number of governmental agencies involved in the management of water-related statistical data, including the National Bureau of Statistics, Ministry of Water Resources, Ministry of Environmental Protection, Ministry of Housing and Urban-Rural Development, China Meteorological Administration and related sector associations. In order to collect water-related data to meet the needs of water resources management and the formulation of related policies, those agencies have all established their own data collection and statistical system and statistical data reporting system and issues have arisen given the involvement of multiple agencies. First, the fragmentation of statistical responsibilities in government has resulted in overlapping data collections, gaps in the data available and the use of a range of methods, standards and concepts. Second, because of the difference in the methods, standards and concepts used to collect water data, it is difficult to integrate data from different sources. Related to this is the lack of information about data quality and the inability to undertake a meta-analysis. Third, there is a lack of legal and technical mechanisms for data exchange between different government agencies. Applying the standard concepts, classifications and methods of water accounting has helped to overcome the technical and methodological problems, although some barriers to interdepartmental cooperation remain.

In order to continue developing the national accounting and environmental-economic accounting of water and to address some of the issues raised above, China is conducting an inaugural census of water suppliers throughout the country. The investigation will collect both

Table 8.6 China's statistical indicator system for water resources

Indicators	Unit	Sources
State of water resources		
1 Annual total quantity of water resources	km^3	Ministry of Water Resources of China (MWR)
2 Precipitation	mm, km^3	MWR
3 Annual amount of flow to sea	km^3	MWR
4 Comparison between current year total quantity of water resources and normal	%	MWR
5 Average water resources amount per capita	m^3	MWR, National Bureau of Statistics of China (NBS)
6 Rate of water resources development and utilization	%	MWR
Water use by industries and households		
7 Total annual water usage	km^3	MWR
8 Total annual water consumption	km^3	MWR
Efficiency of water use		
9 Water use per capita	m^3	MWR, NBS
10 Water use per 10000 yuan of GDP	m^3	MWR, NBS
11 Water use per 10000 yuan of added industrial output value	m^3	MWR, NBS
12 Water use per m^3 of irrigated farmland	m^3	MWR
13 Leakage rate of pipelines and networks in urban	%	Ministry of Housing and Urban-Rural Development of China (MOHURD)
14 Integrated water price of 35 important cities	Yuan	National Development Reform Commission
Water resources protection and ecological remediation		
15 Wastewater discharge and emission to river/lake	10^8 tons	MWR, MOHURD, Ministry of Environment Protection of China
16 Criterion compliance rate of water function zone	%	MWR
17 Percentages of river length of different water quality classes	%	MWR

Table 8.6 (continued)

Indicators	Unit	Sources
18 Degree of groundwater overexploitation	km^3, km^2	MWR
19 Degree of water and soil erosion and recovery	10^4 km^2	MWR
20 Total discharge of sediment of main rivers	10^8 tons	MWR

Source: Preliminary Statistical Indicator System for Water Resources in China (working group of statistical indicator system for water resources (2009)).

financial and business information from agencies carrying out water supply activities.

Determining Appropriate Water Prices

At present, the price paid by water consumers is largely determined by the government and is generally set at a level lower than the cost of supply. In particular, the price of agricultural water only recovers the operational costs and not all of the capital costs. Under the circumstances of increasingly scarce water resources and serious water environmental degradation, setting appropriate water prices is important for optimizing water sourcing, allocation and management. In general, water price should cover the value of water itself, the cost of the infrastructure used to manage water resources and the cost of environmental damage or environmental damage prevention (Wang et al. 2003).

In order to determine an appropriate price for water, studies using the hybrid supply and use accounts and the economic outputs and water uses of different industries were conducted. The details of the method are beyond the scope of this chapter, but the study determined that the theoretical price for water was 6.1 yuan/m^3 (Gan et al. 2009). This price compares with the transacted prices, which were between 1.5 and 5.6 yuan/m^3 across China.

Providing Ecological Compensation Mechanism Support

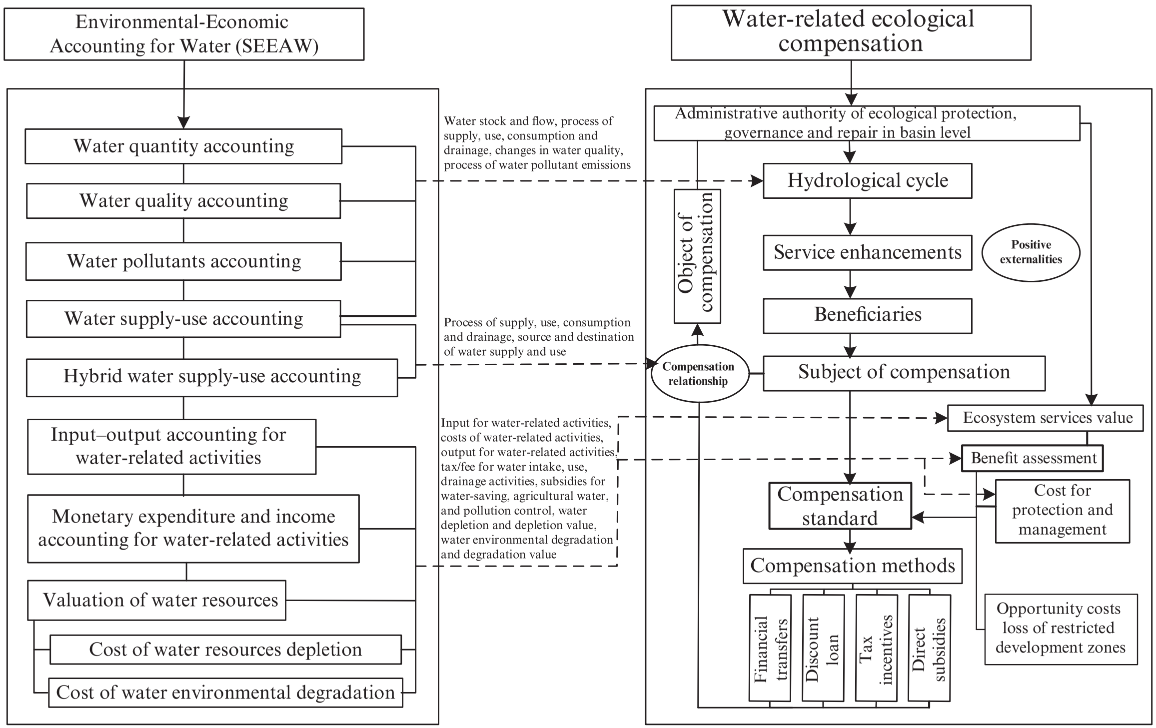
There are many rivers in China that span provinces and municipalities (prefectures) and water use conflicts are liable to occur between those jurisdictions because of water scarcity and water pollution. To spread the benefits and costs of water use equitably, an ecological compensation mechanism is being developed. However, the lack of data on the amount and quality of water diversion and wastewater discharge is impeding the development of the ecological compensation mechanism.

One of the most important purposes of SEEAW is to account for the negative impact of water-related activities by value. So a key issue related to water is the valuation of water resources and the damage caused by human activity. As such, it is important to accelerate the development of the methods used to value the environment as well as the systems used to monitor the environment, the use of natural resources (such as water, energy, land) and measure environment protection activity (Liu 2007). The data from the implementation of SEEAW are being used to support the formulation of mechanisms of water-related ecological compensation in a manner depicted in Figure 8.5.

CONCLUSION

Water accounting systems may develop according to the realities and needs of a particular country. It is desirable to establish a unified framework for water accounting considering the need for comparability and transferability. The current studies in China are based on the SEEAW system recommended by the UN. Because the SEEAW system has not been standardized, it is very necessary to learn from other accounting systems to enhance its general applicability and provide input for the UN to improve the SEEAW system.

The China Institute of Water Resources and Hydropower Research is a national-level research institute and was entrusted by the Ministry of Water Resources and National Bureau of Statistics with responsibility and authority for conducting the water accounting studies described in this chapter. Progress has occurred in the theoretical analysis and the establishment of the framework, however there is still much to be done. The results of the pilot water accounting studies in China were obtained by compiling, analysing and comparing the existing data held by the different agencies. A unified data platform to integrate all the existing data reporting systems is required to improve water accounting data reliability. The Ministry of Water Resources is the governmental agency in charge of water administration in China and all the provincial-level water administrations work under the guidance of the ministry. However, some water-related affairs are managed by other governmental agencies (such as urban water supply under the charge of the Ministry of Housing and Urban-Rural Development and management of pollutant discharge under the Ministry of Environmental Protection). For development of water accounting in China to continue, intensified cooperation between the ministries is necessary.



Source: Gan et al. *(2009)*.

Figure 8.5 Data support of SEEAW resources for ecological compensation

In less than five years a suite of water accounts has been developed for China at the national level and for selected regions. The accounts have consolidated existing information and have been used for a range of policy purposes. Continued development of the Chinese Water Accounting Framework will require close cooperation between government agencies in China in terms of coordinating data collection and data availability. It will also require government decision-makers being made more aware of the water accounting framework and its potential uses in policy development and water resource management.

Water accounting in China has already demonstrated significant benefits in the consolidation of data and for establishing effective partnerships nationally and internationally. The regular production of accounts will provide a time series of information that will be very valuable to policymakers and decision-makers, alike.

NOTES

1. Water function zones are zones with water quality meeting different needs defined according to the status of the environment, use and needs of social and economic development of different parts of water body.
2. Working group of statistical indicator system for water resources (2009). Preliminary Statistical Indicator System for Water Resources in China.

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9. Two perspectives of water resource accounting: comparing the Australian and the United Nations approaches

Eric Mungatana and Rashid Hassan

INTRODUCTION

Natural resource accounts (NRA) comprise a system of satellite accounts[1] for the environment that can be used to incorporate the role of the environment more fully in the economy through the System of National Accounts (SNA). The SNA constitutes the primary source of information about the economy and is widely used for analysis and decision-making in all countries. However, the SNA has had a number of well-known shortcomings regarding the treatment of the environment (Solow 1974, 1986; Hartwick 1977; Lange et al. 2003), with the consequence that the traditional indicators deriving from its implementation (for example, net national income) do not give the correct signals regarding changes in inter-temporal welfare.

To address this shortcoming the United Nations (UN) has developed satellite accounts called the System of Environmental-Economic Accounting (SEEA) (United Nations 1993, 2003). The SEEA complements the SNA for deriving environmentally adjusted indicators of economic performance and change in wealth measures such as genuine savings, which provide better indicators of sustainable development (Weitzman 1976; Hartwick 1990; Mäler 1991; Hamilton 1994, 1996; World Bank 2000). The SEEA recommends that NRA should be constructed for subsoil resources; water resources; wooded land, timber and forest resources; aquatic resources;[2] land and ecosystems to the extent that data permit. In this chapter, we concentrate on accounting for water resources. It is important to note that water accounting is one of the many tools that to date have been developed for water resources management. Other tools include the water footprint approach and integrated water resources management, each of which is discussed in other chapters of this book. The ensuing discussion needs to be interpreted within this broader context.

Applying the guidelines derived from the System of Environment-Economic Accounting for Water (SEEAW), water accounting could be defined as an approach that integrates physical water accounts (which derive from water sector statistics) and water-related economic accounts (which are routinely compiled by national statistics offices). The purpose of this form of water accounting is to increase knowledge about the interaction between water and human activity and by so doing, provide a tool for water management (Lange and Hassan 2006).[3] Population growth, the structure and level of economic activity, urbanization and increasing living standards, land cover and land use changes all influence the availability and use of water. It follows that a tool that links water supply and use with all these factors is valuable for water management. In particular, the information provided by a comprehensive set of SEEAW accounts[4] can identify the following (ibid.):

1. The consequences of economic growth and population growth for water use and availability.
2. The contribution of economic activities to particular environmental problems, such as overexploitation of groundwater, water pollution or loss of aquatic biodiversity.
3. The economic implications (macroeconomic and sectoral) of water policy measures. Such policies include those directly affecting water, such as water allocation and pricing regimes, abstraction regulations and infrastructure development, as well as those indirectly affecting water such as irrigation agricultural development schemes, hydroelectric power development and urban concentration.

SEEAW accounts, either alone or in conjunction with other information, can provide vital information on the economics of water supply and use. This can enable policy-makers to monitor not only the physical, but also the economic implications of changes in water supply, use and water allocation. The economic analysis enables policy-makers to make more informed choices regarding infrastructure development and efficient allocation and use of water for different economic and social activities. In addition, water flow accounts can be combined with economic models to explore the impacts of alternative water-specific as well as general economic policies, such as impacts of various pricing regimes, introduction of water conservation technologies, agricultural development and land use changes and various economic growth strategies (for example, export-led economic growth).

Various countries have constructed water accounts using different approaches that reflect the country's water issues and the availability of data (Lange et al. 2003). France, which was the first country to construct water accounts in recent times, attempted to model all aspects of the hydrological cycle in addition to water quality and water quantity accounts (INSEE 1986). The French water accounting framework has also been used in Spain (Naredo and Gascó 1995), Chile (Meza et al. 1999) and Moldova (Tafi and Weber 2000). Several developed and developing countries have also attempted to implement the SEEAW (Lange et al. 2003; Lange and Hassan 2006). Most recently, Australia also has developed a conceptual framework and an exposure draft of a different system of water accounting standard for water resources (WASB 2009, 2010).

The purpose of this chapter is to compare the system of General Purpose Water Accounting (GPWA) developed in Australia and SEEAW with a view to informing how national and international water resources policy could be optimized from the opportunities provided by the two. The rest of this chapter is organized as follows. First, we summarize the main objectives of the GPWA conceptual framework and provide a comprehensive summary of how this framework recommends water accounts should be compiled and used. We repeat this process in the following section with respect to the UN framework for water resources accounting. We then compare the two systems, emphasizing that the principal distinction between these systems relates to the primary purpose for which each system of water accounts is designed. Finally, we discuss how resource management policy can benefit from the two accounting systems.

GENERAL PURPOSE WATER ACCOUNTING

The foundation for GPWA is the Water Accounting Conceptual Framework (WACF), which provides the conceptual basis for the formulation of Australian Water Accounting Standards (AWAS) and preparation of GPWA Reports. The WACF, published in 2009, is now operationalized as Exposure Draft of Australian Water Accounting Standard 1, The Preparation and Presentation of General Purpose Water Accounting Reports (ED AWAS 1) (WASB 2010).

The Water Accounting Conceptual Framework

The WACF was developed in response to the Council of Australian Governments National Water Initiative requirement for the development of water resource accounting to ensure that 'adequate measurement, monitoring and reporting systems are in place in all jurisdictions, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recorded and managed for environmental and other public benefit outcomes' (WASB 2009, Preface, para. 1). Pursuant to this objective, the WACF provides the foundation for developing AWAS to guide and instruct the preparation of GPWA reports. The WACF comprises a series of concept statements covering, among other matters, (1) definitions of the water accounting elements (water assets, water liabilities, changes in water assets, changes in water liabilities and net water assets), (2) the recognition criteria for those elements, (3) the quantification attribute and unit of account for those elements and (4) disclosure requirements. GPWA reports are intended to provide information to users for use in (1) making and evaluating decisions about the allocation of resources and (2) understanding and evaluating the accountability of managers, management groups or governing bodies of the water report entity for the water resources of the water report entity (WASB 2009).

The purpose of the WACF is to (1) assist water accounting standard setters to review existing AWAS and develop future AWAS consistent with the framework; (2) assist water accounting standard setters to promote the comparability and harmonization of current or potential national and international water accounting regulations, standards and procedures, relating to the preparation and presentation of GPWA reports; (3) assist preparers of GPWA reports to apply AWAS and to deal with topics that have yet to form the subject of an AWAS; (4) assist assurers to form an opinion as to whether GPWA reports conform with AWAS; (5) assist users of GPWA reports to interpret the information contained in GPWA reports prepared in conformity with AWAS; and (6) provide those who are interested in the work of the water accounting standard setters with information about the concepts underpinning the formulation of AWAS (WASB 2009, Preface, para. 5).

To deliver on these purposes, the WACF is presented as a series of Statements of Water Accounting Concepts (SWAC). These concepts are summarized below.

1. *Water report entity (SWAC1)*: the WACF defines a water report entity as an entity in respect of which it is reasonable to expect the existence of users who depend on the GPWA reports for information about water, rights or other claims to water, which shall be useful to them for making and evaluating decisions about the allocation of resources (WASB 2009, SWAC1 para. 11).

2. *Objective of GPWA reports (SWAC2)*: according to the WACF, the main objective of GPWA reports is to provide information useful to users for making and evaluating decisions about the allocation of resources. To facilitate the provision of such information, the WACF requires GPWA reports (WACB 2009, SWAC2 para. 8–9) to: (a) be prepared in a manner that assists users to evaluate accountability for the management of water resources; (b) disclose information that assists users to assess compliance with relevant externally imposed requirements or with broader best practice relevant to water reporting entities; and (c) include independent assurance to users as to whether the components of the report are prepared and presented in accordance with the requirements of the WACF, AWAS and other associated generally accepted water accounting principles and practices.
3. *Qualitative characteristics of GPWA Reports (SWAC3)*: for GPWA reports to satisfy their intended objective, the WACF requires them to possess qualitative characteristics, or attributes, that make the information useful to report users for making and evaluating resource allocation decisions. The principal qualitative characteristics considered are relevance, faithful representation, comparability, verifiability, timeliness and understandability (WASB 2009, SWAC3 para. 7–8).
4. *Elements of GPWA reports (SWAC4)*: the elements of GPWA reports are water assets, water liabilities, net water assets, changes in water assets and changes in water liabilities (WASB 2009, SWAC4 para. 8).
5. *Recognition of the elements of GPWA reports (SWAC5)*: recognition is the process of recording the elements in the GPWA reports (WASB 2009, SWAC5 para. 8). The WACF provides guidelines specifying when an element can be recognized in a GPWA report as a water asset (WASB 2009, SWAC5 para. 9), a water liability (WASB 2009, SWAC5 para. 10), a net water asset (WASB 2009, SWAC5 para. 11), or a change in a water asset or a water liability (WASB 2009, SWAC5 para. 12).
6. *Quantification of attributes of elements of GPWA reports (SWAC6)*: quantification is the process of determining the amount at which an attribute of an element of GPWA reports should be recognized in a particular statement of the report (WASB 2009, SWAC6 para. 8). The WACF provides the guidelines for the quantification of an element, including the following process: (a) selecting the appropriate attribute of an element (for example, volume), (b) selecting the appropriate unit of account (for example, megalitres), (c) selecting the appropriate

quantification approach (for example, modelling or gauging) and (d) using the combined unit of account and quantification approach to determine the amount of the attribute of the element to report in the GPWA reports (WASB 2009, SWAC6 para. 9).

7. *Compliance disclosures of GPWA reports (SWAC7)*: the WACF provides the framework for determining what information GPWA reports should disclose to assist users to assess compliance with relevant externally imposed requirements or with broader notions of best practice relevant to water report entities (WASB 2009, SWAC7 para. 11).
8. *Assurance of GPWA reports (SWAC8)*: the WACF specifies that GPWA reports shall contain an independent attestation that they have been prepared in accordance with approved water accounting standards and other approved pronouncements governing the content of the report and are consistent with the concepts in the WACF (WASB 2009, SWAC8 para. 9). The WACF requires such attestation to be conducted in accordance with applicable auditing and assurance standards and ethical standards and principles related to integrity, objectivity, professional competence and due care, confidentiality and professionalism (WASB 2009, SWAC8 para. 10).

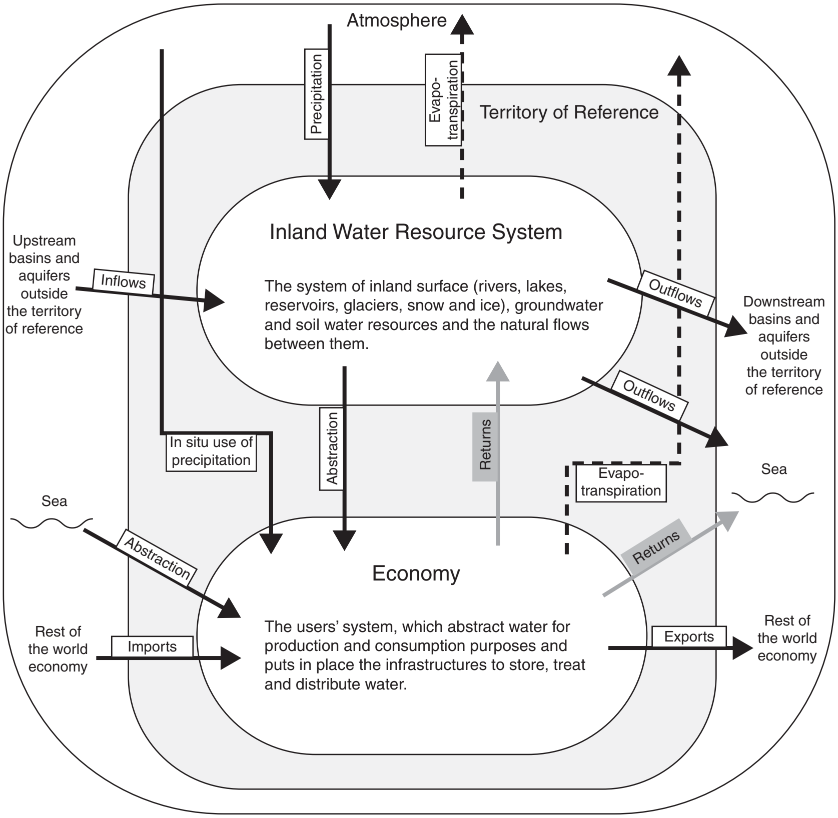
General Purpose Water Accounting Reports

General Purpose Water Accounting reports are a communication tool to inform users about how water resources have been sourced, managed, shared and utilized during the reporting period by or for a water report entity. Further, the reports can enhance public and investor confidence in the amount of water available, allocated, traded, extracted for consumptive use and removed and managed for environmental and other public benefit outcomes (WASB 2009, Preface, para. 2). To deliver on these objectives, GPWA reports contain the following statements where applicable (WASB 2009, Preface, para. 10): a contextual statement, an accountability statement, a statement of water assets and water liabilities, a statement of changes in water assets and water liabilities, a statement of physical water flows, note disclosures and an assurance statement.

The GPWA system has been piloted extensively in Australia and also trialled overseas (see Hughes et al., Chapter 6 and Andreu et al., Chapter 7 in this volume). It is now the subject of an Exposure Draft of Australian Water Accounting Standard 1 (ED AWAS) (WASB 2010), and has been applied by several water report entities in Australia. It also underpins the Australian National Water Account.

SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING FOR WATER

The UN System of Environmental-Economic Accounting for Water (SEEAW) is a specialized system of water accounting that describes most of the hydrological cycle, from precipitation and soil water to the abstraction and use of water for human activities and the returns of wastewater, treated or untreated, back to the environment. This is schematically captured in Figure 9.1 for a generic territory. The upper part of the figure represents the inland water resource system of the territory, technically considered as a stock, whose services flow into the economic system (the lower part of the figure). The total stock of



Source: United Nations Statistics Division (2003, p. 18)

Figure 9.1 Flows between the economy and the environment water is the sum of the quantity contained in surfacewater, soil water and groundwater. The arrows labelled inflows, outflows, precipitation and evapotranspiration are designed to show that the concept 'stock of water' is dynamic in the sense that the balance between inflows and outflows determines whether the stock grows over time, remains constant (a steady state) or diminishes. The services of the stock are pumped into the economic system through the process of abstraction. Once water is in the economy, the SEEAW is designed to physically trace how water is abstracted by industry (as an input to production) and by households (as a final consumption good). After water circulates through households and industry, it could be directly released to the natural environment (return flow arrows), or it could be passed through another industry either for processing before release into the natural environment (sewerage works) or as an input in the downstream (receiving) industry (for example, water released from a hydropower dam used downstream for irrigation). For the flows within the economy, the SEEAW is designed to provide volumetric information and, to the extent possible, monetary information.

To comprehensively capture the flows between the environment and the economy, the SEEAW is composed of the following main components (Lange and Hassan, 2006):

1. Water flow accounts record the flow of water between the economy and the environment, including the supply, use and return of water by industry and households. These are usually organized in the format of a supply and use table (SUT) that is similar to the SUT compiled for national income accounts. The main tables include:
   (a) physical water flow accounts that record the volume of water supplied by an agent either for own use or for delivery to another user, and the volume used by industry and households;
   (b) monetary water flow accounts that record the cost of delivering water to the user and the tariff charge for that water, the difference between the two being the effective subsidy; and
   (c) wastewater accounts, the component of the SUT that records the volume of wastewater discharged after use. Monetary wastewater accounts record the cost of treating wastewater and the user charge for wastewater treatment.
2. Emission accounts record the volume of pollution emitted to a water body. Monetary emission accounts record discharge fees, if any, for wastewater. Water pollution can also be measured in monetary terms as the cost of damage caused.

3. Water asset accounts report the amount of the total resource and changes in the resource over the accounting period (usually a year, although in the case of surfacewater, a case can be made for seasonal surface accounts). Groundwater resources, lakes and dam storage correspond reasonably well to the stock concept, although it is often difficult to establish empirically the volume of groundwater and its recharge rate. However, surfacewater, mainly rivers, does not fit easily into the concept of a stock. Consequently, countries have developed a range of supplementary indicators to assess the volume of the resource available. The water stocks also include a measure of water quality, although this element has not yet been fully developed in the SEEAW. In principle, stocks of water can be valued like any other asset, although asset valuation is very challenging and has not yet been applied to water accounts, except on a case study basis.
4. Water value is also included. The natural characteristics of water and the fact that it does not necessarily have a cost to the user (for example, precipitation), along with its public good attributes have prevented the emergence of a competitive market for water in the vast majority of uses impeding the establishment of a market price that reflects the economic value of water. Observed tariffs are usually set administratively on the basis of supply costs or on the basis of affordability in order to ensure that water is available to the majority, if not all, people. Consequently, the observed prices are not a useful guide to policy-makers trying to assess the economic value of water in different uses. Because of the difficulties involved with the valuation of water, no country's water accounts have comprehensively included valuation, except on a case study basis. As discussed elsewhere in this volume, China is attempting to integrate water valuation into its SEEAW-based accounts.

The SEEAW is a vast, comprehensive system, and to the best of our knowledge, no country has yet implemented all its components (refer to Table 9.1). All countries applying any part of SEEAW start with the physical water supply and use table, usually with greatest emphasis on the use accounts because they have been found most useful for policy analysis (Lange and Hassan 2006). In some countries where pollution is important, wastewater and pollution accounts have been compiled. Monetary accounts are important for water policy, and many countries have compiled at least partial monetary accounts, but data have been more difficult to obtain than for physical accounts. In the next section, we show how the SEEAW framework has been applied in South Africa.

Table 9.1 Countries adopting SEEAW

Country	Stock Accounts	Flow Accounts		
		Physical	Monetary	Wastewater and pollution
Developed				
Australia	Partial	X		X
Denmark		X	X	X
France	Partial	X	X	X
Germany		X		X
Netherlands		X	X	X
New Zealand		X	X	
Spain	Partial	X	X	
Sweden		X	X	X
Developing				
Botswana	Partial	X	X	
Chile	Partial	X	X	
Moldova		X	X	X
Namibia	Partial	X	X	
Philippines		X	X	X
South Africa	Partial	X	X	

Note: X = constructed accounts.

Source: Lange and Hassan (2006, p. 10).

APPLICATION OF SEEAW TO SOUTH AFRICA

The water economy of South Africa is characterized by high demand and competition for water, diminishing low-cost sources of additional water supply and growing water quality problems (Hassan 1997; Gillit 2004; Hassan and Crafford 2006). Limiting factors on the supply side include low and erratic rainfall patterns, naturally limited groundwater resources, exhaustive development of available water storage and transfer options and invasion of catchment areas with alien plant species (Hassan and Crafford 2006). This is matched by a growing demand owing to continued economic expansion, rapid urbanization and a new water policy environment that corrects for historical biases in water allocation to ensure access to water for production and domestic use to millions of previously excluded citizens and sustenance of ecological systems (ibid.).

Hassan and Crafford (2006) constructed water resource accounts for South Africa intended to be used as a tool to improve the ability of water management authorities, national economic development agencies and environmental policy agencies to better manage the pertinent water scarcity crisis. They based the construction of the water accounts on the SEEAW framework. However, to establish consistency between the water accounts they constructed and the principles of water management in South Africa on one hand, and the mandate of the principal water management institutions in South Africa on the other, they had to adapt key features of the physical and monetary components of water flow and asset accounts of the SEEAW to the South African context. The key adaptations are summarized in the following. First, the water supply and use tables of the SEEAW focus on water flows between the economic system and the environment and flows within the economy (between economic units). In this structure, water flows occurring exclusively within the environment are not explicitly included as an integral component of the supply and use tables. Moreover, since the primary focus of the SEEAW is on economic abstraction, storage and release of dam water is considered part of the hydrological cycle and not an economic activity, owing to the difficulty with separating discharge for direct economic use from releases to manage water flow and regulate runoff during floods and dry seasons. Interference with water flows within the environmental sphere, however, is one key feature of water management in South Africa. This necessitates modifying the SEEAW to capture explicitly key water flows within the environment that are the target of strategic water management in South Africa and are consequently influenced directly by Department of Water Affairs and Forestry (DWAF) decisions and actions. Second, in situ (passive) water uses are not explicitly included in the SEEAW as they do not involve removal of water from the environment. However, the South Africa National Water Resource Strategy (NWRS) makes protection of aquatic ecosystems and human need a priority in water allocation, which also necessitates modifying the SEEAW to capture this aspect.

Since the NWRS divides the country into 19 Water Management Areas (WMAs), accounts were initially constructed for each WMA and then aggregated to the national level. Data for the accounts were derived from three published reports: (1) the Water Resources Situation Assessment (WRSA) conducted by the South Africa DWAF for 1995, (2) the National Water Resources Strategy and (3) Internal Strategic Perspective Reports published by DWAF for each of the 19 WMAs. Three components of the SEEAW were constructed: (1) physical water flow accounts, (2) physical water asset accounts and (3) monetary water flow accounts.

The physical water flow accounts (SUTs) are tables that detail the supply and use of water resources for South Africa in 1995 and 2000. These SUTs were constructed for natural sources of water supply (defined to include the atmosphere and sea, natural mean annual runoff, surfacewater, groundwater, soil water and ecological reserve) and institutional sources (which include DWAF, irrigation boards, water boards, municipalities and rest of the world). In addition, water use and discharge tables by production sectors were also constructed. The sectors of production were agriculture (dryland and irrigation, livestock, forestry), mining, electricity, other bulk industrial, other commercial and industrial, domestic urban and domestic rural. Tables 9.2 and 9.3 reproduce the key SUTs for natural and institutional sources of water respectively. In the physical water asset accounts, Hassan and Crafford (2006) compiled the water balance for South Africa (Table 9.4) and the physical accounts for groundwater resources in South Africa (Table 9.5).

To compile the monetary water flow accounts, Hassan and Crafford (2006) combined the physical data of Tables 9.2 through 9.5 with data sourced primarily from Statistics South Africa's national accounts. In these accounts, they initially analysed how much various economic users spent on water in 2000. This enabled them to derive the average cost per unit of water employed by the economic sector. They established that trade and services sector paid the highest cost per unit of water employed in 2000 (R12/m^3), followed by mining (R3.76/m^3) and domestic use (R1.19/m^3). According to this analysis, agriculture paid the least cost (R0.023/m^3) while water used in electricity generation cost only R0.50/m^3. Hassan and Crafford (2006) then used data from the national accounts for 1995 and 2000 to construct income and employment indicators. They established that while agriculture had the highest share of water use (about 80 per cent), it contributed only 3 per cent of national income in 2000. Conversely, trade and services used only 8 per cent of the water to contribute about 70 per cent of total national income in 2000. Manufacturing produced close to 20 per cent of total income in 2000 with only about 6 per cent of water. Consequently, trade and services had the highest GDP/m^3 indicator among all activities followed by manufacturing, mining and last agriculture. The pattern was similar with respect to employment indicators. They finally provided an extended discussion on the water tariff system (charges and preferential subsidies), their implications for cost recovery and service delivery and important gaps in availability of key data necessary for construction of key indicators that need to be addressed viz further disaggregation of water use by economic activity; improved knowledge on the role of dryland crop

Table 9.2 Natural sources of water in South Africa in 2000 (million m^3)

Supply Table		Environment					
		Atmosphere & sea	Natural MAR[a]	Surface water	Groundwater	Soil water	Ecological reserve
Environment	Atmosphere & sea		29 467				9 545
	Natural MAR[a] (including storage)	49 040					
	Surface water (including reserve)		19 573				
	Groundwater	1 088					
	Soil water	55 400					
	Ecological reserve			9 545			
Distribution	DWAF (available total yield)			9 597	1 088		
	Irrigation boards						
	Water boards						
	Municipalities						
	Rest of world and other WMAs						
Production	Agriculture			431		55 400	
	Dryland & irrigation					45 000	
	Livestock & game						
	Plantation forestry			431		10 400	
	Mining						
	Electricity						
	Other bulk: industrial						
	Other commercial & industrial						
	Total domestic						
	Domestic – urban						
	Domestic – rural						
Total supply		105 528	49 040	19 573	1 088	55 400	9 545

Table 9.2 (continued)

Use Table		Environment					
		Atmosphere & sea	Natural MAR[a]	Surface water	Groundwater	Soil water	Ecological reserve
Environment	Atmosphere & sea		49 040		1 088	55 400	9 545
	Natural MAR[a] (including storage)	29 467		19 573			
	Surface water (including reserve)						
	Groundwater						
	Soil water						
	Ecological reserve	9 545					
Distribution	DWAF (available total yield)	186					
	Irrigation boards						
	Water boards						
	Municipalities						
	Rest of world and other WMAs						
Production	Agriculture	63 389					
	Dryland & irrigation	52 245					
	Livestock & game	313					
	Plantation forestry	10 831					
	Mining	326					
	Electricity	234					
	Other bulk: industrial	237					
	Other commercial & industrial	784					
	Total domestic	1 404					
	Domestic – urban	1 143					
	Domestic – rural	261					

Table 9.2 (continued)

Use Table	Environment					
	Atmosphere & sea	Natural MAR[a]	Surface water	Groundwater	Soil water	Ecological reserve
Total use (U)	105 567	49 040	19 573	1 088	55 400	9 545
Theoretical ecological reserve						9 545
Water balance						186
Consumption (U − S)	39	0	0	0	0	39

Note: a. Total quantity of surface flow, which is the average annual runoff originating from a certain geographic area, is referred to as the mean annual runoff (MAR).

Source: Hassan and Crafford (2006).

Table 9.3 Institutional sources of water in South Africa in 2000 (% of total)

Supply Table		Distribution Sectors				
		DWAF	Irrigation boards	Water boards	Municipalities	Rest of world
Environment	Atmosphere & sea	2				
	Natural MAR[a] (including storage)					
	Surface water (including reserve)					
	Groundwater					
	Soil water					
	Ecological reserve					
Distribution	DWAF (available total yield)				28	100
	Irrigation boards	63				
	Water boards	32				
	Municipalities	1		74		
	Rest of world and other WMAs					
Production	Agriculture		100			
	Dryland & irrigation		100			
	Livestock & game	2				
	Plantation forestry					
	Mining			9		
	Electricity			7		
	Other bulk-industrial			9		
	Other commercial & industrial				27	
	Total domestic					
	Domestic – urban				39	
	Domestic – rural				6	
Total supply in million m^3		12 623	7921	4092	4380	39

Table 9.3 (continued)

Use Table		Environment				
		DWAF	Irrigation boards	Water boards	Municipalities	Rest of world
Environment	Atmosphere & sea					
	Natural MAR[a] (including storage)					
	Surface water (including reserve)	76				
	Groundwater	9				
	Soil water					
	Ecological reserve					
Distribution	DWAF (available total yield)		100	100	3	
	Irrigation boards					
	Water boards				69	
	Municipalities	10				
	Rest of world and other WMAs	0.3				

Table 9.3 (continued)

Production	Agriculture					
	Dryland & irrigation	4.7				
	Livestock & game					
	Plantation forestry					
	Mining				1	
	Electricity				1	
	Other bulk – industrial				3	
	Other commercial & industrial				10	
	Total domestic					
	Domestic – urban				13	
	Domestic – rural					
Total use (U) in million m^3		12 623	7 921	4 092	4 380	
Consumption (U − S) in million m^3						(39)

Note: a. Total quantity of surface flow, which is the average annual runoff originating from a certain geographic area, is referred to as the mean annual runoff (MAR).

Source: Hassan and Crafford (2006).

Table 9.4 Annual changes in water flow volumes and yield of the water system in South Africa in 2000 (billion m³)

Annual Changes to Water Stock	2000
A. Changes due to natural processes	
A1. Precipitation	611.600
A2. Evapotranspiration and deep seepage	−506.067
A3. Gross annual runoff[a] (A1 – A2)	105.528
A4. Transpiration from dryland agriculture (including plantations)	−55.400
A5. Replenishment of groundwater	−1.088
A6. Natural MAR (A3 − A4 − A5) (% of total precipitation)	49.040 (8%)
A7. Base flow[b] and other natural leakages from MAR	−29.467 (40%)
A.8 Surface water yield (A6 − A7) (% of MAR)	19.573 (40%)
B. The ecological reserve (in stream flow requirements – IFR)	−9.545
C. Changes due to human activity	
C.1 Cultivated forest incremental use	−0.431
C.2 Available surface water yield (A.8 – B – C.1) (% of MAR)	*9.597 (20%)*
C.3 Available groundwater yield	*1.088*
C.4 Usable return flows	*1.899*
C.5 Transfers from rest of world (water imports)	*0.039*
C.6 Total available yield (C.2 + C.3 + C.4)	12.623 (26%)
C.7 Total abstraction by production activities	*−12.437*
D. Net annual change in flow water volumes (BALANCE)	0.186

Notes:
MAR = mean annual runoff.
a. Gross annual runoff measures surface water flow volumes after losses through evaporation, seepage and use by natural vegetation (transpiration) are deducted from falling rains. This represents water available for dryland farming, cultivated forests, MAR and groundwater replenishment.
b. The base flow represents the groundwater component of river flow or MAR.

Source: Hassan and Crafford (2006).

farming and livestock production in the physical accounts; data on self-supply of water and the share of self-providers in total water use and supply; data on financing of water supply and subsidies on water use by various supply institutions and use sectors; data on the economic, social and environmental values of water; data on water use by social groups and data on water quality.

Table 9.5 Groundwater physical accounts for South Africa, 1995–2000 (billion m³)

	1995	2000
1. Natural MAR	44.33	49.04
2. Ecological reserve	4.58	9.55
3. Net MAR	39.75	39.50
4. Base flow (billion m^3)[a] (% of MAR)	11.93	11.85 (24%)
5. Groundwater recharge	1.207	1.09
6. Annual recharge (rows 4 + 5)	13.14	12.94
7. Total groundwater stocks[b]	17.28	17.76
% of net MAR	44%	*45%*
8. Groundwater storage (row 7 – row 4) (% of net MAR)	5.35 (18%)	5.91 (15%)
9. Net groundwater storage (row 8 – row 5)	4.14	4.82
Exploitable groundwater potential[b]	9.04	9.48
% of net annual runoff (row 1)	23%	*24%*

Notes:
MAR mean annual runoff.
a. The base flow represents the groundwater component of river flow.
b. Groundwater storage measures the theoretical available groundwater, whereas exploitable groundwater potential measures utilizable groundwater that can actually be abstracted at reasonable costs.

Sources: Council for Scientific and Industrial Research (2001); Vegter (1995); Baron et al. (1998).

DISCUSSION AND CONCLUSIONS

While both GPWA and the SEEAW are designed with the express objective of enhancing water resources management, their key difference lies in the intended objective of the final output. The main objective of GPWA is to provide information in a way that can enable report users to rationally evaluate how water has been sourced and used and the availability of water to meet obligations to supply water. Fundamentally, GPWA reports are communication tools. General Purpose Water Accounting prescribes the characteristics that GPWA reports must exhibit to enable them to be effective in communicating important information about water and what the characteristics the information needs to possess if it is to be important to users. The focus of GPWA is the report user and the accounts must be presented in such a way that the end user will derive benefits from the availability of the water accounting information. Consequently, the development of GPWA has addressed matters including the nature of the information the accounts should contain, the quality requirements information must satisfy and how the accuracy of the information can be verified. These features mirror those of financial reporting. Presumably it is because of the need to instil public understanding and confidence in water management that a report commissioned to analyse Australia's water accounting practices (Sinclair Knight Mertz 2006) recommended a disciplinary approach to developing water accounting standards based on that used for financial reporting (WASB 2009). Financial accounting is a well-established discipline, with a long tradition and the reports (and conventions) deriving from financial accounting are easily accessible to a very wide audience.

In contrast, the main objective of the SEEAW is to combine physical information from hydrology (water flows, water stocks, water balance) with income and expenditure information from the SNA to facilitate an enhanced understanding of environmental–economic relationships. One of the main identified weaknesses of the traditional SNA is its inadequate representation of environmental stocks and environmental flows into the economic system, leading to incomplete indicators of sustainability. Consequently, the emphasis of the SEEAW is the collection and compilation of information that fits within the accounting conventions of the SNA. Thus, instead of defining users of water accounting reports as stakeholders with an interest in the activities of a water management authority, the SEEAW would define a water accounting entity with respect to a unit whereby compiling measures of economic activity in accordance with strict accounting conventions based on economic principles would be reasonable. The use sectors of the SEEAW SUTs will be defined, to the extent possible, according to the SNA's International Standard Industrial Classification (ISIC) of economic activities. For more examples, we note that supply table in Table 9.2 shows that 105 528 million cubic metres of water was supplied in South Africa in 2000 from the atmosphere and the sea (sum of natural MAR, groundwater and soil water). The use table in Table 9.2 shows how the quantity of water supplied was allocated across the environmental spheres and the using economic sectors listed in column 1. If it was methodologically possible to convert the physical information on stocks and flows of Table 9.2 into commensurate monetary units, this would fit within the reporting conventions of the SNA where everything is reported in monetary units.

The supply and use information reported in Table 9.3 (by institutions) should be interpreted likewise. Thus, for example, irrigation boards supplied 100 per cent of the water requirements for irrigation agriculture in 2000 (supply part) and likewise, they received 100 per cent of their water requirements from DWAF (use part). With appropriate valuation, this is information that can be used in the SNA. From such an integrated environmental-economic database, one can compute the indicators earlier reported in the application of the SEEAW to South Africa. It follows that the emphasis of the SEEAW is on the integration of environment-economic data to support the development of indicators for sustainability. After satisfying the mandatory water requirements (for example, human survival and mandatory environmental requirements in the South Africa example), the application of the SEEAW can also help us address questions about resource allocation efficiency. For example, does the water allocation depicted in Table 9.3 maximize social welfare? If it does, the current situation is desirable; otherwise which reallocation amounts to a Pareto-optimal improvement?

NOTES

1. Satellite accounts are accounts that are linked to the national accounts through a common set of definitions and classifications, but which do not affect the core values of the national accounts (Lange and Hassan 2006, p. 7).
2. Aquatic resources are broader than water resources and accounting for them can include accounting for resources such as fisheries and marine mammals.
3. Countries in eastern and southern Africa have constructed water resources accounts to provide a tool for improved water resources management (in particular, comparing the relative desirability of different water allocation regimes). However, some water accounting systems also provide information that serves other purposes beyond water management. For example, General Purpose Water Accounting is a system developed to provide information to parties external to management (while potentially also assisting management) for purposes that may include water policy development, water pricing and decisions whether to invest in equity or debt of entities with water-related risk.
4. The accounts produced under the SEEAW usually comprise 12 standard tables (see Part I Chapter 2). We refer to this as a complete set of accounts.

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PART III

Contemporary issues addressed by water accounting

10. The impossible planetary trust: intergenerational equity, long-term investment and water governance and regulation

Gordon L. Clark and Claire Woods

INTRODUCTION

The management of water over the long term involves the interests of current and future generations. As is the case with the management of any scarce natural resource, water management necessarily raises questions about intergenerational equity. Population growth and development put an increasing strain on water resources. If current rates of growth continue, global annual water use is expected to increase to 6.9 trillion cubic metres by 2030, an increase of 2 trillion cubic metres from global annual water use in 2010 (Gilbert 2010). This is 40 per cent more than the current water sources provide (ibid.). Climate change presents additional uncertainties to the availability of water across space and time over the next century (Intergovernmental Panel on Climate Change 2007). The management of water for the future is, increasingly, an immediate concern.

The purpose of this chapter is to conceptualize intergenerational equity in resource management, particularly water, as an important factor in long-term investment decisions. Invoking Brown Weiss's (1984) seminal treatise on the virtues of an intergenerational perspective for the management of the environment, the chapter contemplates how her proposed planetary trust, an institutional solution to the problem of governing long-term commitment, can contribute to water resource management.[1] The chapter offers a critique of the planetary trust concept, noting in particular its parallels with defined benefit (DB) pension funds. Similar to an obligation to manage the environment for future generations, a DB fund carries obligations to different generations, with time horizons as long as 80 to 100 years. The problem, though, is that these types of institutions have struggled to be effective long-term investors. Crucially, the trustees of these institutions often fail to balance the competing interests of current and future beneficiaries, typically focusing on short-term rather than long-term outcomes. Where they succeed, they remain vulnerable to intervention by the state on behalf of current generations (who are, of course, its constituents). The chapter concludes by examining the management of Australia's Murray Darling Basin water resources through the lens of the planetary trust. In doing so, it recognizes that water accounting can contribute to the balancing of current and future generations' interests in water over the long term.

INTERGENERATIONAL EQUITY

The protection of natural resources requires long-term planning. However, from individuals (Kahneman and Tversky 1979) to organizations (Clark et al. 2006, 2007), societies tend to focus on short-term goals. While families have an immediate interest in the future of their own children, this interest usually does not translate into a broader interest in the future of society. For governments, moreover, there is a temptation to focus on short-term usage at the expense of long-term interests because of the immediate political benefits of rewarding local interests (Clark 2009a). Present leaders generally ignore future generations' interests when they are not represented in decision-making or in the political process (Brown Weiss 1989). For business, a similar short-term logic applies. A longer-term environmental strategy does not necessarily increase returns over the short term or (sometimes) even the long term (Florida and Davidson 2001). Both government and business tend to prioritize short-term interests over long-term interests given the more general conceptual and political challenges posed by the notion of justice between generations. While Ostrom (1990) has demonstrated that in some circumstances local communities can manage common natural resources in a sustainable, long-term manner, it is unclear that the approach Ostrom (ibid.) describes could be successful on a larger scale.

The Planetary Trust

Achieving justice between non-contemporaneous generations with respect to environmental matters is difficult theoretically and practically (Thompson 2009). While a number of theorists have attempted to establish a normative basis for justice between the generations (Rawls 1971; Fishkin and Laslett 1992; Thompson 2009), very few have suggested an instrumental means of governance for achieving justice between generations. An exception is Brown Weiss (1984, 1989) whose theory 'tries to anticipate the norms required to bring about justice between our generations and future generations' with respect to 'the natural and cultural patrimony of our planet' (Brown Weiss 1989, p. 2). Brown Weiss has suggested an *instrument* that legislators could adopt in order to give effect to the theory of intergenerational equity: the 'planetary trust'. It is:

> a normative framework which, if adopted and internalized by our political, economic and social institutions, might enable them to serve as vehicles for ensuring that future generations will inherit their just share of our global heritage. Its thesis is that the human species holds the natural and cultural resources of the planet in trust for all generations of the human species. (Brown Weiss 1984, p. 498)

This concept (institution) is based in trust law. Brown Weiss describes it as follows:

> This planetary trust obligates each generation to preserve the diversity of the resource base and to pass the planet on in no worse condition than it receives it. Thus, the present generation serves both as a trustee for future generations and as a beneficiary of the trust. In fulfilling our role as planetary trustees, we can draw on the law of trusts, a body of distilled teachings concerning intergenerational cooperation and conflict, to help resolve the challenges confronting our global heritage. (Brown Weiss 1989, p. 499)

As such, the planetary trust institution conceives the entire planet as a trust fund, which must be managed by trustees in the best interests of beneficiaries. Brown Weiss relies, in particular, upon the law of charitable trusts in order to constitute her legal framework for the planetary trust. Trust law in common law jurisdictions requires that several features be present in order for a trust to exist. These include the capital of the fund itself, beneficiaries, trustees, an (explicit or implicit) decision to create the trust and rules governing the management of the trust (Langbein 1995).

First, at the heart of a trust fund is the trust property. The property of the planetary trust 'includes both the natural heritage of the planet and the cultural heritage of the human species' (Brown Weiss 1984, p. 502). Second, trustees manage the trust fund on behalf of the beneficiaries. In charitable trusts, the beneficiaries do not need to be ascertainable (identified individuals). Instead, the trust should 'benefit society at large or an appreciable part of it' (Oakley 2003, p. 443). The beneficiaries of the planetary trust are to be 'all human generations, born and unborn' (Brown Weiss 1984, p. 503). Third, the trust must have trustees who manage the trust property with a high level of care, according to the requirements of fiduciary duty (for example, Langbein 1995). Under the planetary trust 'each generation acts as trustee for beneficiaries in succeeding generations, just as past generations served as trustees for it' (Brown Weiss 1984, pp. 504–5). Fourth, the purpose of the trust must be clear. The owner of the trust property must manifest an intention that it be held on trust for the beneficiaries. Brown Weiss argues that:

> [t]he planetary trust is an *inter vivos* trust between generations of the human species. Its existence is implicit in the nature of the relationship between generations. It derives from an implied declaration by each generation that it holds the resources of the planet in trust for future generations. This intention is universally reflected in diverse human cultural and religious traditions. (ibid., p. 504)

Brown Weiss's assumption that all humans intend to hold the planet in trust for all future generations is, of course, somewhat utopian. Her suggestion that this intention is universal and manifest in 'diverse human cultural and religious traditions' is, similarly, morally and practically contentious. It relies upon a belief that the regard one generation has for its children is *natural* in the sense it is *a*historical and not contingent on culture and society and is repeated one generation to the next by reference. It also relies upon the longevity and continuity in the institutional form and functions of that commitment (the trust entity). It is unclear whether Brown Weiss intended this concept to be taken as anything more than a moral or ethical construct, but she did acknowledge the *potential* for a more formal institution:

> [w]hile no affirmative action need be taken to create the planetary trust as a moral obligation, to have legal force it must be effectuated by positive law. Thus, the members of each generation must confer legal status on the trust by enacting and enforcing positive laws affirming their obligation to future generations. (ibid.)

The planetary trust concept has several advantages. First, it conceptualizes the intergenerational problems inherent in natural resource management. Second, it emphasizes the role that could be played by the current generation in ensuring future generations have access to a range of quality natural resources and not just what is left over after thoughtless exploitation by the current generation. Third, and most importantly, it presents a theoretical framework upon which a functional instrument may be designed and managed. In Merton and Bodie's (2005) terms it has a form and function.

Despite these advantages, the planetary trust concept is problematic on institutional, political, legal, economic, moral and even ecological grounds. While a full critique of the planetary trust concept is beyond the scope of this chapter, we present an institutional critique of the planetary trust, arguing that despite its several advantages, the concept is problematic (for a further critical look at the planetary trust concept, see Woods 2011a, 2011b).

Comparison with Funded Pension Schemes

Most obviously, the notion of the planetary trust sidesteps the (real) risk of intergenerational conflict between current and future beneficiaries of the trust. The maintenance of environmental resources for future generations may require the restriction of the current generation's access to these resources. In such situations, planetary trustees are forced to choose between the interests of their own generation (often vociferously) and future generations (largely unrepresented). While Brown Weiss notes that the 'dual role of trustee and beneficiary create [sic] conflicts' (1984, p. 508), she does not offer a way of transcending this conflict other than evoking (once again) the natural relationship and commitment between one generation and their children. Even if plausible, it is not necessarily adequate as a means of joining generations many years removed. The planetary trust lacks a means by which people are able to give voice to their interests, assuming they have interests other than the shared welfare of their children (and a means by which adherence to trust values and objectives may be understood). This particular deficiency of the planetary trust underlines the importance of mechanisms for accounting for natural resources requirements – something that water accounting sets out to achieve.

Moving from the theoretical to the material, the planetary trust institution is very similar to funded pension schemes and especially DB pension funds, which have, in recent years, revealed themselves to be largely unsustainable (Clark et al. 2006, 2007). These schemes are a type of occupational pension plan that are trust funds set up by companies, organizations or industries to provide an income to employees and their survivors after they retire (Oakley 2003). In DB funds, employers agree to set aside a certain portion of employees' current wages and pay them a certain income upon their retirement (ibid.). As a result, employers bear the risks of the invested trust fund. If it underperforms against estimated liabilities, the employer has to fund the deficit (ibid.). In many funds, younger, middle-aged and older generations of workers coexist together, paying in their contributions with the employer or sponsor as those retired draw their entitled benefits. The fund functions well as long as no generation exploits the others and the sponsor remains solvent with respect to assumed liabilities and current contributions and obligations. As such, it can be a self-perpetuating trust aligning the welfare of different generations.

Like the planetary trust concept, DB funds under Anglo-American law are based on trust law. They have:

1. fund capital (that is, a pool of capital produced by the company or organization creating the DB fund);
2. beneficiaries (employees of the company or organization);
3. trustees;
4. trust purposes; and
5. evidence of the intention of the trust when created.

These elements differ only slightly from those Brown Weiss described with respect to the planetary trust. For instance, while the current beneficiaries of a DB fund are ascertainable, being past or present employees of the company or organization, the fund accepts new members not yet determined. Whereas all people are trustees of the planetary trust, the trustees of DB funds are representatives of those participating in the fund. Even if DB funds are bound by a trust deed, the planetary trust is presumably bound by an implicit social contract that may have as much force as it would have if explicit.

Whatever the significance of these differences, there are strong similarities between the planetary trust and the structure of DB funds. In particular, DB funds face a similar challenge to that of the planetary trust fund with respect to the management of conflicting intergenerational interests within the fund. It is arguable that the institution of the DB fund has failed in Anglo-American countries in part because younger generations of workers have not valued the institution as highly as older generations of workers. Where salary sacrifices have been asked of younger participants, they have opted, more often than not, for alternative forms of retirement saving that favour the short term over the long term. For example, younger employees will often opt to join defined contribution (DC) pension funds over DB funds because they are aware that they are likely to leave their current employer and want to take their pension contributions with them (this is not usually possible in DB funds) (see Clark and Monk 2008, especially at p. 13; see also Clark 2009b). In other words, they value the mobility of DC funds. Furthermore, when given the choice, younger employees tend to minimize their current contribution to their DC pension funds (see generally Clark et al. 2009). By contrast, older employees, for whom impending retirement looms larger, have generally preferred DB funds to DC funds, thus sacrificing stability for mobility (Clark and Monk 2008). Older employees within DC funds are more willing to make larger contributions to their DC pension fund (Clark et al. 2009). The trust institution contains competing interests that are nominally bound together by a commitment to the future. More subtly, but perhaps more insidiously, short-term biases in trustees and asset managers lead them to focus on the short-term performance of a fund (either a DB fund or planetary trust). In practice, this strengthens the position of the generation that benefits more immediately from the trust fund relative to future generations.

This difference in preferences between younger and older generations within DB funds comes to the fore when those responsible (usually trustees, sometimes union negotiators) determine the amount of benefit to be paid to retirees at any one time, and whether and to what extent to adjust that benefit to account for the cost of living. When addressing this intergenerational conflict, DB funds have two main potential courses of action, both of which may also have implications for the planetary trust. In the absence of common agreement over the appropriate level of retirement benefit to be paid at any one time, the trust institution, through its trustees, may have to override some interests in favour of the notional 'common good'. If the resistance of current or future retirees to a proposed level of retirement benefit is too great, the state that underwrites the formal status and legitimacy of the trust may have to intervene to enforce the trustees' decision with respect to what the common good requires. By this assessment, the Achilles' heel of the planetary trust, like DB funds, is its reliance upon state intervention. If we rely on external sources to overcome the tensions within the trust fund, then the purposes and powers of the trust, vested in the responsibilities of its trustees, are less sacrosanct. Granting the possible need for coercion, would the planetary trust be effective as a long-term investor on our behalf?

INTERGENERATIONAL CONFLICT AND THE MURRAY DARLING BASIN

This chapter has outlined and critiqued the concept of planetary trust as an institutional arrangement for conducting intergenerational environmental management. In doing so, it has discussed the parallels with intergenerational conflict within DB funds. In this section, the management of Australia's Murray Darling Basin (MDB) is used as a case study to illustrate conflicts that exist with long-term water resource management. The history and significance of the management of the MDB, both for Australia and internationally, is described. Looking through the lens of the planetary trust, the management of the MDB is considered with particular focus on the structure and independence of the governing authority, the Murray Darling Basin Authority (MDBA), in the long-term management of the MDB. Further, some of the challenges facing the sustainable or long-term management of the MDB are identified, with particular reference to the initial public response to the release of the MDBA's Plan for the MDB on 8 October 2010.

The MDB, which spans parts of the Australian Capital Territory, New South Wales, Queensland, South Australia and Victoria, is Australia's most significant river system. The MDB hosts 39 per cent of Australia's total agricultural production and contains about 65 per cent of Australia's irrigated land (MDBA 2010). Water was first diverted from the River Murray in the 1880s and it soon became clear that the quantity of water available for use would become problematic (ibid.). In response to growing concerns about the quantity and quality of water in the MDB, Australia's Commonwealth and relevant state governments (New South Wales, Victoria and South Australia in 1987, followed by Queensland in 1996 and the Australian Capital Territory in 1998) agreed to a coordinated plan for the MDB. The agreement failed to prevent a decline in the health of the MDB, however, and various iterations were agreed, culminating in 2007 with the Water Act 2007 (Commonwealth of Australia 2007). As of October 2010, 20 of the 23 major river valleys in the MDB are in poor to very poor ecological condition (MDBA 2010).

The Water Act established the MDBA, an independent authority charged with giving effect to its various requirements. Most essentially, the MDBA is required to produce a Basin Plan for the MDB. The MDBA released a preliminary Basin Plan, entitled the 'Guide to the Plan', on 8 October 2010. As part of the Plan, the MDBA had to establish sustainable diversion limits (SDLs) to the amount of water available for consumptive uses (ibid., p. 103). The MDB Basin Plan was created following:

> extensive scientific analysis of the Basin's ecology, identification of the key environmental assets and key ecosystem functions and their water requirements, detailed hydrologic modelling using models developed by Basin states and the [MDBA], and detailed social and economic analyses to assess the potential impacts of meeting the environmental water requirements of the Basin (ibid., p. iii).

As such, it provides relevant context to (and could perhaps benefit from) the concept of water accounting contained in the System of Environmental-Economic Accounting for Water (SEEAW), which is 'a conceptual framework for the organization of physical and economic information related to water'.[2]

The MDBA's SDLs, as presented in the *Guide to the Proposed Basin Plan* (the Guide), following years of unsustainable water use, would result in a significant reduction in water available for consumption if adopted. Using the planetary trust analogy, the Water Act has required the MDBA to create a plan for the long-term sustainability of the MDB for future generations, which will mean curtailing the access of current generations to the water resources of the MDB. The Water Act requires the MDBA to identify SDLs with reference to the following two broad objectives:

> To establish SDLs that reflect an environmentally sustainable level of take (Water Act s. 23(1)) which is a level of extraction that will not compromise the environmental water requirements of key environmental assets including water-dependent ecosystems; ecosystem services and sites with ecological significance; key ecosystem functions; the productive base and key environmental outcomes for the water resource. That, in doing so, the economic social and environmental outcomes are optimised and the net economic returns maximised. (ibid., p. 103)

The MDBA recognizes that establishing SDLs will create hardships for rural communities whose collective livelihoods are tied to the use of MDB water resources at the current level of consumption. The Guide acknowledges that from an ecological perspective, a reduction from current diversion limits of up to 7600 GL (gigalitres) would be preferable, but would result in too severe an impact on communities. Instead, the Guide recommends SDLs that require reductions of 3000 to 4000 GL from current diversions, an average reduction of 22 to 29 per cent across the MDB, and up to 45 per cent in some regions. The Australian government has already committed to recovering 2000 GL of this through water buybacks or investment in efficient irrigation under the 'Water for the Future' Program (ibid., p. 151), and intends to bridge the remaining gap through further water buybacks from irrigators.

The release of the Guide on 8 October 2010 was met with strong opposition from some irrigators and rural parliamentarians. Irrigators expressed anger about water being allocated to the environment to the detriment of communities. Others suggested that 'there could be riots in the streets' (Herbert 8 October 2010) and Barnaby Joyce MP announced (erroneously) that the proposed SDLs would put Australia's food security at risk: the majority (60 per cent) of Australia's food is exported (Roberts et al. 2009). These arguments are all underlined by a preference for the short-term interests of current water users over the long-term interests of future water users (see Woods 2011a). Hyperbole and hysteria aside, the introduction of the recommended SDLs will impose a heavy burden upon many communities. Under such circumstances, the MDBA faces intense political pressure to reduce the burden its proposed SDLs would place on current generations (ibid.). However, unless minimum ecological conditions within the MDB are maintained, its water resources will become unfit for both environmental and economic future uses.[3]

MDBA THROUGH PLANETARY TRUST LENS

The MDBA is an independent statutory authority created by the Water Act. Its role under the Water Act endows it with responsibilities with respect to the long-term planning of the MDB that are not unlike those of planetary trustees. The Water Act requires the MDBA to establish SDLs for the purpose of facilitating the long-term sustainability of the MDB while allowing for the social and economic requirements of the current generation with respect to water. As such, the MDBA has been given an intergenerational responsibility much like that of trustees for the planetary trust.[4]

A strong water accounting method will contribute to the balancing of current and future generations' interests in a transparent manner. In this light, a crucial contribution may be made to the field of water accounting from the arguments of proponents of generational accounting more generally. Generational accounting is 'a method of long-term fiscal analysis and planning . . . [i]ts goals are to assess the sustainability of fiscal policy and to measure the fiscal burdens facing current and future generations' (Auerbach et al. 1999, p. 1). Auerbach et al. (1999) present generational accounting results from 17 countries. In doing so, they expose some of the imbalances in intergenerational equity in the fiscal policies in several countries around the world, including Australia, Germany and the United States.

The early reaction to the Guide's release is a demonstration of the intergenerational conflict inherent in the planetary trust. Any reduction in current SDLs represents an economic loss to the current generation of water users and a gain to the future water users due to the enhanced long-term sustainability of the MDB. This trade-off is, of course, complicated by the fact that future generations may also be negatively affected by reduced economic productivity today. This illustrates the key theoretical deficiency in the planetary trust concept being played out – future generations cannot, of course, respond to the vociferous opposition of the current generation of water users to the proposed reduction of water available for consumptive purposes. It is up to the MDBA, in its trustee-like capacity, to put forward a generationally balanced plan for the MDB. Whether the Guide will withstand immediate opposition from those currently affected by its requirements remains to be seen. In the highly politicized arena in which the Guide has been released, moreover, it is not only the content of the Guide but also the manner in which its content is communicated, that will determine its acceptability. The MDBA may already be showing signs of strain: by 18 October, ten days after the release of the Guide, the MDBA had announced that it would hire consultants to conduct a further study of the likely social and economic impacts of the SDLs. By the end of

November 2010, three separate inquiries into the socioeconomic impact of the Guide's proposals had been announced (one by the Senate, one by the House of Representatives Standing Committee on Regional Australia and one by the MDBA itself (Stone, 2011).

If the Guide proves sufficiently unpopular, it may lead to the repeal or amendment of the Water Act to rebalance the intergenerational scales toward the interests of current water resource users of the MDB, effectively foregoing the longer-term sustainability of the MDB. As with any legislative instrument, the Water Act is not immune from repeal or amendment. As for the planetary trust and DB funds, the trump card of government legislation may ultimately alter the generational balance set by the independent trustee-like institution, the MDBA.

CONCLUSION

This chapter has portrayed intergenerational equity as an issue of long-term investment, arguing that the trust institution (whether in the form of Brown Weiss's planetary trust or a DB fund) offers the promise of long-term resource management. In reality, however, the success of these institutions is often illusive. Trustees of these institutions are required to balance the competing interests of current and future generations in the management of the funds and are often preoccupied with short-term performance to the detriment of long-term sustainability. Even where trustees are able to resist the temptation to favour the short term, political pressure from current beneficiaries means that the trust funds are exposed to the risk of government intervention on behalf of the present generation.

Looking through the lens of the planetary trust, one can compare the MDBA to planetary trustees. Like planetary trustees, the members of the MDBA are required to manage the resources of the MDBA, planning for the future by determining the long-term environmental requirements of the MDB, while at the same time taking into account the social and economic needs of the current generation of users of the MDB. Therefore, the MDBA is charged with the intergenerational task of balancing competing interests of current and future users of the MDB water resources (as well as those who rely indirectly on the economic, social and environmental well-being of the MDB). Opposition to the MDBA's Guide demonstrates the difficulty outlined in this critique of the planetary trust. Namely, in the face of the anger of the current generation, protection of resources for future generations becomes difficult.

In the search for robust institutions fit for a particular purpose, democratic governments have often recognized the value of politically independent bodies for tasks that require long-term planning. These institutions' missions are best served by the practice of keeping short-term political battles at arm's length. Governments undergo a recursive struggle in determining not only how best to design these institutions, but also whether and when to intervene in the institution of their creation, foregoing the independence for which it was formed. The iterative process involves the isolation of an institution from political pressure for a time, followed by the eventual intervention of governments in response to the very democratic demands that the independent authority was designed to avoid. In creating the MDBA, the Australian Commonwealth has shielded itself, to an extent, from the political fallout of decisions by the MDBA that might prove politically unpopular. More importantly, they have recognized that the MDBA's task requires long-term decision-making of a sort suited to insulation from immediate political demands. Despite the governments' tacit acknowledgement of the value of independent authorities in long-term decision-making, the democratic imperative remains ever present. Should the decisions of the MDBA prove too politically unpopular, the Water Act may be amended or repealed. The recommendations of the MDBA, an independent, appointed body, aim to protect the interests of future, as well as present, generations of MDB users. Whether they will withstand political pressure remains to be seen.

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NOTES

1. Brown Weiss's notion of a planetary trust has been resuscitated by Barnes et al. (2008) in their 'atmospheric trust'. Arguing that 'climate change will require drastic departures

from business as usual' they suggest a 'visionary' governing entity for the 'management and protection of the global commons' (p. 724). Drawing upon the trust institution, which is recognized as a 'well-developed legal mechanism designed to protect and manage assets on behalf of specific beneficiaries', Barnes et al. (ibid.) acknowledge that its global mandate may have to begin at the regional or national levels. Unlike many governments' environmental policies, the atmospheric trust would use market instruments to realize long-term goals of innovation and adaptation 'for the benefit of current and future generations' (ibid.).

2. See UN Statistics Division (2007), http://unstats.un.org/unsd/envaccounting/pubs.asp; accessed 22 February 2011.
3. Separating the terms 'environmental' and 'economic' uses belies the fact that these are often intertwined and sometimes mutually reinforcing.
4. The MDBA's interpretation of the Water Act, particularly how the ecological interests of the MDB should be weighed against its economic and social interests, has been debated. It is worth noting that the MDBA has worked closely with the Australian Government Solicitor throughout the preparation of the Guide, including receiving legal advice on the Water Act's interpretation: see Woods (2011b).

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11. Water accounting, corporate sustainability and the public interest

Mike Muller

INTRODUCTION

The goal of water accounting should be to support better decision-making about water and its use by enabling key performance indicators to be monitored. Ideally it should do this in a manner that is neutral between competing interests. However, just as science is seldom strictly neutral in its real world application, neither is accounting, and approaches that are deemed better for some people may be deemed worse for others. As two Organisation for Economic Co-operation and Development (OECD) commentators note:

> Indicators are invariably developed to inform and influence different societal, political, technical and institutional processes . . . a composite indicator developed by an environmental Non Government Organisation (NGO) will probably have more success raising awareness among the general public, than as a widely-accepted information tool among government analysts. (Scrivens and Iasiello 2010, p. 9)

Different approaches to hold corporate water users accountable for the sustainability of their water use have been proposed, focusing on physical water accounting. However, indicators are not neutral and the accounting approaches chosen will not always produce socially optimal or sustainable results.

This chapter considers whether and how approaches to water accounting and information from the accounting process can help to achieve the goals of water resource management. It focuses on some of the approaches to water accounting that large business enterprises have been encouraged to adopt in order to improve the sustainability of their water use. It also illustrates how inappropriately applied water accounting may contribute to outcomes that are suboptimal for particular communities. It concludes with guidelines for approaches that can inform policy issues and address different interests in a balanced way.

THE OBJECTIVES OF WATER RESOURCE MANAGEMENT

The overarching goal of water resource management has been defined as the achievement of the optimal use of water in the public interest (DWAF 1997). The apparent simplicity of this goal is deceptive. Water is both an essential resource for most human activities and an environmental ecosystem in its own right with inherent social and cultural as well as economic values. While linked by a global hydrological cycle, it has limited physical transportability and tradability and its exploitation is primarily a local matter.

However, water resources often transcend the boundaries of political jurisdictions, at all levels from local to continental, and the impacts of use in one location may have a major impact elsewhere. So it is seldom obvious, amongst a range of directly interested parties and broader stakeholders, whose preferences should take priority in decisions about water and its use since the interests of those different groups are often not aligned and may be in conflict. Even within its strictly economic dimension, water is not obviously a public or a private good. An extensive literature seeks to understand the challenges of managing what some describe as a 'common pool resource'. And the issues are sufficiently complex to have merited a Nobel prize for Elinor Ostrom who provided a conceptual framework to explain how sustainable management can be achieved (Ostrom 2009).

The challenge in the development and application of water accounting systems is to recognize the inherent complexity of decision-making about this resource with its multiple roles and multitude of different configurations, and to elucidate the underlying issues.

WHO ACCOUNTS TO WHOM FOR WHAT: ACTORS AND THEIR INTERESTS

An immediate issue in the development and application of water accounting processes is to determine who is accounting to whom, and for what purpose? In analysing this, three sets of actors are considered, each with different, sometimes conflicting, sets of objectives. The actors include public policy actors, corporate actors and environmental advocacy actors:

1. Public policy actors at political and administrative levels have formal objectives to promote the public interest by actions that minimize externalities and maximize welfare gains in a manner that reflects public preferences. These actors operate at a range of scales and contexts and the interests of one jurisdiction are often not congruent with those of others.
2. Corporate actors include both individual companies, seeking to manage risk and build their competitive advantage, and their associations, which seek to reduce regulatory burdens and promote the role of private business. The focus is on large business enterprises with global or regional presence and reputations.
3. Environmental advocacy actors operate at a global level to promote environmental policy positions, which often reflect the preferences of interest groups far removed from the communities and societies concerned, although they may act through local organizations.

FROM CORPORATE RESPONSIBILITY TO CORPORATE SUSTAINABILITY

Context and Goals

Although the challenges of water management and accounting extend beyond the areas in which the private sector is involved, corporate water use attracts considerable attention. One reason is that the use of water by the private or corporate sector covers a very wide range of activities. In addition, the corporate actors offer an attractive target for environmental advocates who promote their policy preferences by imposing reputational (and occasionally business) risk on them.

To understand the context in which water accounting is being applied to, and in, the corporate sector, it is helpful to review the evolution of current approaches to corporate sustainability, which are part of the initiatives to take corporate accountability beyond traditional financial reporting. These initiatives were driven initially, in the 1970s, by concerns about labour standards, health, safety and corruption as well as more conventional financial matters such as transfer pricing. However, they moved beyond these issues to include a broader focus on the environmental impact of business activities. The 1987 Brundtland Report, 'Our Common Future' (World Commission on Environment and Development 1987) placed the concept of sustainable development firmly on the global policy agenda. This milestone initiative explicitly highlighted the need for industry to adopt socially responsible approaches, stating that 'Industry's response to pollution and resource degradation has not been and should not be limited to compliance with regulations. It should accept a broad sense of social responsibility and ensure an awareness of environmental considerations at all levels'. The Brundtland Report gave impetus to a range of actions both by business and by external parties such as environmental NGOs. Two decades later corporate sustainability is entrenched as good practice, with companies producing sustainability reports detailing their environmental and social performance in addition to their economic performance.

Generic Instruments for Corporate Responsibility and Sustainability

The focus on sustainability as a dimension of corporate social responsibility has generated a variety of instruments to monitor performance, which have to be underpinned by accounting systems. One generic intervention was to promote formal regulatory oversight of business activities at a global and regional level. This response followed a landmark intervention in the field of health and consumer protection where, in 1981, the World Health Assembly of the World Health Organization (WHO) called for a mandatory code of conduct to govern the marketing of infant foods (WHO 1981).

Efforts to establish compulsory international codes of conduct were met in many cases by industry proposals for voluntary codes. These were often seen as an attempt to control the policy agenda and to avert compulsory regulation, which led to compacts or standards being negotiated. Standards developed by industry together with regulators and the broader public may enjoy greater legitimacy as instruments for corporate social responsibility than voluntary frameworks and codes of conduct produced solely by industry. Furthermore, standard setting is a familiar process for the corporate actors.

Standardization for environmental management derived from work on quality control, which focused on processes rather than products – the ISO 9000 standards apply military contracting approaches to the performance of service providers. This approach was extended to the ISO 14000 standards for environmental management. As the International Organization for Standardization (ISO) explains, 'the intention of ISO 14001:2004 is to provide a framework for a holistic, strategic approach to the organization's environmental policy, plans and actions . . . (it) does not lay down levels of environmental performance' (ISO 2010).

Corporate Sustainability: Whose Preferences and What Indicators?

The establishment of regulations or performance standards is part of the process of achieving policy goals and assumes that appropriate indicators and accounting systems are available to provide information for performance monitoring. The need for appropriate indicators was illustrated by health sector debates over the use of injectable contraceptives in developing countries after they were restricted in developed countries for safety reasons. It was realized that policy-makers had to consider not only drug side-effects but also differences in maternal mortality rates since in richer countries the drug was more dangerous than pregnancy, while in poorer countries it was safer (Muller 1982). This demonstrated that standards need to reflect the context in which they are applied and that 'accounting data', in this case the rate of side-effects, could be inappropriately applied. Only with appropriate accounting and indicators, in this case the overall reduction in risk, could sensible decisions be taken.

The challenge is to choose the appropriate indicator for the particular policy goal and context and to design an appropriate accounting system for it, recognizing that while global standards and indicators may be appropriate in some fields, in others they must be context specific. With this perspective, we can turn to the specific issues of water accounting and corporate sustainability.

ACCOUNTING AND ACCOUNTABILITY IN THE WATER SECTOR

Indicators of Water Use Sustainability

How can corporate responsibility be exercised in the water sector? How can the sustainability of corporate water use be assessed? And how can water accounting contribute to addressing these issues? Some global and regional regulatory measures are already in place that can help to assess the performance of corporate actors. The Ramsar convention protects wetlands at a global level, a UNECE convention governs the protection and use of European transboundary watercourses and a European Community (EC) directive sets minimum levels for the treatment of urban wastewater.

At a national level, corporate use of water is invariably regulated although legal approaches differ widely between countries. Such regulation typically covers the allocation of water between users (sometimes with provision for the amount of water to be reserved for the environment), the protection of water resource quality from pollution as well as the development of water infrastructure.

Corporate water users will usually be concerned to ensure that they comply with regulations. However, mere compliance is no assurance of sustainability. In many countries, regulations are poorly framed and compliance poorly enforced. Corporations may follow local practice and take advantage of poor enforcement, comply regardless of the costs incurred or not comply, since to comply when others do not may reduce competitiveness. A further option is to engage to improve water management to achieve acceptable sustainability. This option may either be triggered or, alternatively, stifled by the accounting approaches adopted. All these options assume that there is an understanding of sustainability in water resources and how it may be assessed.

Water Stress

Sustainability is generally defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. But what are the needs of present generations? Specifically, how much water do today's societies require to be sustainable and how does today's use of a renewable resource affect tomorrow's potential users?

A widely used indicator is the water stress index, the total annual renewable water resources per capita (Falkenmark et al. 1989). For countries to be self-sufficient in food production (which accounts for the bulk of world water use), it was assumed that availability of 1700 m^3/capita/year was the threshold above which water shortage occurs only irregularly or locally. Below 1700 m^3/capita/year water stress appears regularly, below 1000 m^3/capita/year water scarcity is a limitation to economic development and human health and well-being and below 500 m^3/capita/year water availability is a main constraint to life. While the water stress index has been challenged, it continues to be used, particularly to provide comparative information about overall water availability at a national level.

Water Use

For businesses, the first step in assessing water use sustainability is to obtain information about their water use and discharges. Many businesses do not monitor water consumption as a matter of routine and tracking waste discharges and loads, the actual amount of pollutant in a waste stream, often requires special effort.

If reports were available for all water users, further information could be compiled to put this water use into context. Examples of information that could be compiled include how much water is used in a particular geographical area and the proportion of that use attributed to a particular user. While this will address comparative water use, it conveys no information regarding the sustainability of the water usage or its social, economic and environmental costs and benefits.

Water Use Efficiency and Productivity

Water use efficiency, the output achieved per unit of water, is a metric that can inform managers (and regulators) about the comparative performance of their plants or industry. Such benchmarking can help analysis and decision-making by revealing available options and identifying potential best practice performance.

For policy purposes, water productivity, the inverse of efficiency, considers water per unit product rather than product per unit water. This information may be useful for businesses to assess (if not make choices about) their environmental impact and sustainability and has been proposed as a first generation of sustainability indicators.

Virtual Water

A limitation of the water metrics described above is that total water used in production is not considered. For example, water used to produce a bottle of beer is not limited to that consumed directly by the brewery. The brewing process uses inputs such as grain and sugar, whose production uses far more water. This suggests that the total amount of water used for a unit of production should include offsite water use.

This insight is reflected in the concept of virtual water, which originated in Middle East conflict resolution efforts where access to water was a sensitive issue (Allan 1998). It was demonstrated that water scarcity was being addressed by importing products that embodied large amounts of water in their production (virtual water) and that this reduced concerns about local water shortages (incidentally highlighting the defects of water stress indicators as a useful indicator of sustainability). More generally, it has been suggested that the concept can be used to assess policy issues such as the impact of dietary choices on the water consumption of different societies.

The Water Footprint

The concept of the water footprint followed logically from 'virtual water' as explained by one of the concept's initial promoters (Hoekstra and Chapagain 2006 and see Hoekstra, Chapter 3 in this volume). Developed explicitly as part of a broader environmental footprint, the water footprint focuses on the water demands inherent in the consumption of one product or by one society, driven by the concern that rich countries were protecting their domestic environments by exporting externalities to other countries. The water footprint allows a distinction to be drawn between direct water consumption and the total water embodied in a community's consumption of goods and services. The footprint concept describes the resource implications of consumption patterns and provides a language for advocacy.

Hoekstra and Chapagain reported that the same product had very different water footprints in different countries. An important factor in this was:

> water-inefficient agricultural practice, which means that water productivity in terms of output per drop of water is relatively low. This factor partly explains the high water footprints of countries such as Thailand, Cambodia, Turkmenistan, Sudan, Mali and Nigeria. In Thailand for instance, rice yields averaged 2.5 ton/ha in the period 1997–2001, while the global average in the same period was 3.9 ton/ha. (ibid., p. 46)

However, this approach does not inform a corporate actor whether water use for rice production in Thailand, sugar production in the Sudan or the products derived from those commodities is sustainable. The implicit value judgement is that water use may be excessive and that excessive water use is bad. This serves to illustrate how inappropriate approaches to water accounting may lead to misinformed judgements.

WATER USE AS A GLOBAL 'BAD'? CRITIQUES OF THE WATER FOOTPRINT, VIRTUAL WATER AND OTHER METRICS

While the concepts of virtual water and the water footprint have proven useful to raise public awareness about the social and economic contribution of water resources as well as about the impact of human activity on the environment, it has been suggested that they have limited analytical significance. Specifically, they create the impression that water is a scarce good whose opportunity cost is generally the same wherever it is found, that its consumption has a negative impact on the physical environment and that this consumption should be reduced (OECD 2010).

This reflects environmental advocacy approaches used to address the generation of CO_2, demonstrably a global public bad (a negative good) whose increased levels are widely agreed to be detrimental to the global climate system, human welfare and ecosystems. Yet water use is not a public bad. Water flows through many natural cycles and is renewable, not destroyed by use but merely recycled. Its consumption does not lead to an overall depletion, although local stocks may be tapped faster than they can be refilled (as with groundwater in South Asia and the western US). Even polluted water is usually purified as it passes through the larger cycle, although specific water bodies may be permanently impacted upon.

This can be illustrated with beef consumption. Grassland-raised beef does not significantly affect local water resources (unless overgrazing results in river flows increasing) even though it embodies substantial amounts of green water (rainfall that is intercepted by soil and returned to the water cycle through plant evapotranspiration). However, beef from animals grain-fed in feedlots embodies water used to produce the feed, which, if irrigated using blue water (withdrawn from surface or groundwater resources) will impact on water resources. Similarly grassland-raised beef will have limited impact on water quality while beef produced in feedlots generates a concentrated stream of effluent that can devastate both surface and undergroundwater resources.

Water use thus does not inevitably damage the global environment even though it may harm local ecosystems. In addition, the water content and impact of specific products varies widely.

BEYOND THE FOOTPRINT AND VIRTUAL WATER

These limitations of virtual water and the water footprint as analytical concepts demonstrate that knowledge of the quantity of water embodied in a product or process is not enough to enable the environmental performance of a company, industry or country to be evaluated nor any business risk inherent in that water use to be determined. In both cases the policy concern is not the absolute volume of consumption but its sustainability and environmental impact. To move from knowledge of the water content of a product or service to knowledge about the environmental or social impact of its production, more information is required. It is to the nature of that additional information that is now addressed.

SCARCITY IN CONTEXT: THE WATER EXPLOITATION INDEX

It is argued that the water footprint provides limited information about sustainability given that the impact of water use will be very different in different contexts. Abstraction from a small stream may irreparably damage its natural ecology while the same volume taken from a large water body or as green water will have negligible impact.

To assess the sustainability of a consumptive water use (where water is taken from the cycle and not directly returned) the volume withdrawn can be set against the amount available in the water body from which it is taken. This apparently simple information can be difficult to obtain in practice and requires a distinction between consumptive and non-consumptive uses as well as of quality changes during use. Nonetheless, this metric can help to understand the overall impact of water-using sectors at national or regional levels.

The European Environmental Agency (EEA) has compiled a Water Exploitation Index (WEI) measured as the mean annual total demand for freshwater divided by long-term average freshwater resources (Lallana and Marcuello 2004). The EEA considers countries or basins as water scarce whenever their water exploitation index is above 10 per cent. But this specific measure is subjective and other organizations use different measures. The UN Intergovernmental Panel on Climate Change (IPCC) used 20 per cent (IPCC 2001, p. 213) while the OECD uses Falkenmark's measure of water use intensity below 10 per cent to be low water stress, 10 to 20 per cent as moderate, 20 to 40 per cent as medium-high and more than 40 per cent as high water stress (OECD 2004, p. 23).

THE LIMITS TO WATER SCARCITY AND EXPLOITATION INDICES AS INDICATORS

The inherently subjective nature of this approach to the definition of scarcity is demonstrated by its implications for different groups of countries. Applying the 40 per cent level in Europe would lead to the conclusion that only one country is water scarce. However, applying the EEA's 10 per cent globally, 61 out of 193 countries would be characterized as water scarce. An approach with more global resonance is thus to take a water use intensity of 40 per cent as a realistic indicator of serious water scarcity: 26 out of 193 countries fall into this category. While many of these are oil producers and small island states, the list includes countries such as Sri Lanka and Pakistan, which are characterized by water-intensive agriculture.

There are other limitations of the metrics discussed. National estimates consider neither the spatial distribution of water and people within a country nor the seasonal timing of supply and demand and do not indicate whether water is readily and realistically available. A distinction is often not drawn between consumptive and non-consumptive water uses (the WEI is overestimated when water used for hydropower and returned to source is included) or to account adequately for water that is serially reused. Further, the metrics do not account for green water.

The WEI offers only a crude overview of the state of water in a catchment or country. It is still not enough to guide corporate actors in assessing their business risk and sustainability contribution. If corporate actors disinvested from countries that are water scarce by EEA norms, they would leave the US, Japan, Germany and Singapore, amongst others. As the IPCC has concluded, 'Simple numerical indices, however, give only partial indications of water resources pressures in a country or region because the consequences of "water stress" depend on how the water is managed' (IPCC 2001, p. 213).

BACK TO CORPORATE SUSTAINABILITY: INDICATORS OF GOVERNANCE

A company wishing to establish a new plant needs assurance that the water it requires will be available over its lifespan and a secure authorization to abstract it. It would want similar assurance about wastewater disposal. If local administrations could give such assurance, then sustainability might be considered to be 'certified'. But assessing the functioning of governance systems is very different from determining how much water is flowing in a river. It involves a significant element of foresight (for example, will the future government uphold today's decisions?) and must consider whether today's social preferences will still be valid tomorrow. This may be risky as evidenced by current campaigns in the US seeking to remove hydropower dams, once hailed as the foundation of industrialization but now seen as environmental liabilities (Rogers 2009).

ACCOUNTING WITH POOR INDICATORS PRODUCES SUBOPTIMAL OUTCOMES

The following examples illustrate the difficulties faced in applying different approaches to water accounting to assess sustainability.

Water Use and Market Access: Footprinting Kenyan Flowers

Horticultural exports from developing countries to North America and Europe have been criticized because of the environmental costs of air freight (Chi et al. 2009) and more recently for their water consumption. Around Lake Naivasha, Kenya, there is extreme competition between rural people for land and water resources. Critics say that local flower production aggravates water shortages and environmental stress and they have campaigned for a boycott of Kenyan flowers. An unspoken dimension of the debate is that water use for cash crops and subsistence at the expense of the lacustrine environment may reflect local social preferences.

While Kenya's greenhouse horticulture is both water efficient and productive, generating more livelihoods and income per unit of water than most other rural water uses, the campaigns have made horticulture more risky and production and employment have fallen (Riungu 2009).

This is an extreme example of policy advocacy, through corporate accountability mechanisms, using simplistic water accounting measures to promote an external policy preference, despite its adverse impacts on the communities concerned. Effective governance is certainly needed to achieve agreed levels of water abstraction and environmental protection in Lake Naivasha. Choices need to be documented and presented in an understandable form and context-specific water accounting could provide valuable guidance to policy-makers and communities alike. But initially, water accounting was used to support external campaigns rather than to meet local needs.

Pollution and Development in Sweden and South Africa

A common metric is the proportion of wastewater treated, which is widely promoted as a global standard to be measured in water accounting processes. But this may be another example of the use of water accounting to support externally imposed preferences for environmental protection.

Standards for water use change over time. Sweden's capital, Stockholm, today enjoys urban waterways whose quality is so good that they are used for recreational purposes, including swimming. However, in the nineteenth century, Stockholm's Norrström River was little better than a sewer, heavily polluted by industrial and municipal waste (Stockholm City Museum 2010). In 2011, many South African water bodies are so polluted that they can no longer safely be used for recreational purposes. Urban populations expanding ahead of the development of adequate sanitation facilities and diffuse pollution from stormwater runoff both contribute to pollution loads. Where sewers are installed, wastewater treatment capacity has often not been increased and plant operation is inadequate (van der Merwe-Botha 2009; PMG 2010).

Yet just as Sweden's industrialization involved a phase of heavy pollution, the current low priority of sewage treatment in South Africa may reflect the preferences of a society in which the majority of the population does not have access to sewage services and did not, until recently, have control over public resources or the voice to make choices. Using wastewater treatment rates to assess the sustainability of South Africa's water resource management would be inappropriate, as the Swedish example has demonstrated. Water accounting should rather be used to lay bare the costs and benefits of wastewater treatment to support informed decisions rather than simply assess compliance with external standards.

Regional Water Quality Becomes a Global Goal

The European Community's Urban Wastewater Directive illustrates how water users in one jurisdiction can be held to account by standards transported from another jurisdiction. The 1991 directive determined that all EC countries would treat their urban wastewater to a high standard (Council of European Communities 1991). This was supported by the European environmental lobby as well as the industrial sectors that construct and operate treatment plants. It also helped achieve the economic policy objective of spending community funds on investment rather than consumption and public acceptance was helped when special EC funds were allocated for the purpose.

While the benefits to the European community have been questioned, the political decision should be respected. However, high wastewater management costs reduce European competitiveness. This could encourage moves to protect the EC's competitive base (extending beyond Europe's borders what some commentators suggest was the initial goal of the directive, to bring southern Europe into line with northern Europe's cost structures).

Through global indicators and accounting systems, developing countries are being encouraged to adopt similar standards despite their different domestic priorities. Policy harmonization is imposed through aid agreements as well as trade barriers when developing country agricultural exports are restricted if irrigation water does not meet European quality standards (Nieuwoudt 2008).

Dams and Development in Uganda and Europe

A further example of policy preferences being enforced through standards linked to accounting procedures is the well-documented opposition to the development of new dams for hydropower and other purposes (Briscoe 2010). Uganda's Bujagali hydropower project was delayed by more than five years by funding boycotts, based on claims that the project would prejudice local interests. The Bujagali project has limited impact on downstream flows, and since its waters cover less than 200 hectares, few households were relocated for its construction (Bujagali Energy Limited 2006). The project's delay had substantial impacts on Uganda's economy, employment and poverty. The electricity shortages that resulted from its delay are estimated to have reduced GDP by as much as 2 per cent per year over five years (IMF 2006) with resulting poverty possibly causing thousands of additional child deaths.

Careful water accounting of the project's costs and benefits might have made a difference, if allied to a respect for the findings. It is incongruous that many of the countries that blocked funding for African hydropower projects rely on hydropower, which supplies 9 per cent of Europe's electricity, its most important source of renewable energy (European Commission 2008).

UNINTENDED CONSEQUENCES

It is recognized, even by the proponents of certain water accounting measures, that they could have unintended consequences:

> First and foremost many of those using water footprinting are emphatically not saying that water footprints should justify changes in international trade. In particular I have sat in sessions with WWF where they have advised consumers not to take consumption decisions based on water footprints . . . it is too early and will mislead. (Personal communication from corporate sustainability manager 2009)

However, the way in which the concept is applied often lies outside the control of its authors. So while conservation NGO WWF and its corporate collaborators discourage the use of footprints to influence international trade, the UK's Royal Academy of Engineering was still suggesting that:

> [b]usinesses can examine their supply chains and production processes to assess and reduce their water footprint as a core component of their corporate social responsibility strategies. Their analysis should not be restricted to their home country but also to those regions from where they import goods, materials and services. (Royal Academy of Engineering 2010, pp. 6–7)

DISCUSSION

Who Accounts to Whom for What? Accountability and Democratic Governance

In all these examples, the key question remains: who accounts to whom for what? In the process of decision-making about water and its use, how are preferences determined? Whose preferences should be given priority? Whose goals should water accounting support?

Where there is clear global impact, as with CO_2 generation, a case can be made for global preferences to take priority. But where the issues are essentially local, it is not obvious that decisions affecting resource allocation and distribution within a society should be taken externally to that society. This is not to restate Lawrence Summers's argument that pollution should be shifted to poor countries (*New York Times* 1992) but rather that they should be able to make their own decisions about what is acceptable to them.

Effective political systems depend, in the long run, on the legitimacy gained by accounting to local communities about local concerns. If water management decisions are enforced by external actors, some short-term objectives may be achieved but effective water management may be weakened in the long term. Indeed, water management is an area in which donor-prescribed policy reform has repeatedly failed in developing countries (Muller 2010).

The Jurisdictional and Temporal Challenges

The challenge from a public interest perspective is that standards and indicators established in one jurisdiction may be imposed, through systems of accounting, in others. International regulatory standards are usually the product of negotiation, in which the stronger interests have both the resources and positional power to enforce their preferences (Drezner 2007).

In this situation there is an obvious risk that the preferences of less powerful and less resourced groups will be sidelined unless the validity of local decisions is acknowledged. In the context of water resources management, the danger is that matters of local relevance and subject to local preferences may end up being inappropriately regulated at a global level. This is already a challenge, as the examples provided have shown.

The fact that preferences change over time as contexts change, as the example of Stockholm demonstrates, makes assessment even more difficult. At any point in the past or future history of a locality, certain water uses will be frowned upon or tolerated. Local accounting systems should reflect and inform local preferences even as they change.

Exit or Engagement

The dilemma for corporate actors is that water accounting may reveal situations of stress, which could be interpreted as risks rather than part of a dynamic process of change. If risk leads business to exit, rather than to engage, underlying social and economic pressures may simply be aggravated. This dilemma is recognized by business leaders in the corporate sustainability context. An important conclusion recently is that businesses should go beyond the plant to the river basin. They can offer resources and ideas to improve the situation, as the flower growers of Kenya have done by generating more jobs and income per unit of water than any alternative that existed before:

> Businesses, government, and civil society share an interest in reducing water-related risks through common solutions. These include a focus on long-term viability, the prioritization of water allocation for basic human and environmental needs, and the flexibility required to respond to the challenges of a dynamic resource system. In the end, solving water problems requires not only better public policy and stronger institutions, but also inclusive and meaningful participation in decision-making by all stakeholders, including business. (CEO Water Mandate 2010, p. 12)

But they can only do that if they engage.

CONCLUSION

This chapter has shown that water accounting is not necessarily neutral and that it can be used to promote sector-specific interests and to advance policies that are not supported by the communities concerned. There is a particular danger where there is capacity and power asymmetry that standards will simply be imposed on weaker parties.

Continued efforts to account better for water and its uses in both physical and economic terms are vital if societies are to manage successfully the growing pressures that they are placing on their water resources. In this, the engagement of corporate actors is important since they are not just the source of many of the pressures but may also become the drivers of innovations to address them. They should not be driven by mechanical notions of high impact and therefore high risk to withdraw from places where the challenges are greatest but rather be encouraged to engage in a systematic way to address the challenges of sustainability.

The difficulties inherent in understanding and quantifying the complex relationships that underpin apparently simple words, such as ‘stressed’, ‘pressures’ and even ‘water resources’, should not be underestimated. A response should be to ensure that accounting frameworks on which standards are based:

1. are feasible and reflective of societal capability;
2. address social and economic dimensions as well as water and environmental dimensions; and
3. do not unnecessarily constrain sustainable development opportunities.

The quality of governance is widely recognized as the most important determinant of water resource sustainability, which can be achieved even under severe stress by good management. A pragmatic approach would harness better water accounting as a contribution to sustainable management, supporting public policy formulation and decision-making, starting with the communities concerned.

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12. Water accounting and conflict mitigation

Lise Pretorius and Anthony Turton

INTRODUCTION

In this chapter, we investigate the relationship between risk management, water and conflict, and ask what role water accounting can contribute in the avoidance or resolution of water-related conflicts. Water accounting, in this context, refers to a system by which flows of water can be quantified and reported, in any given economic or ecological domain. The analysis in the chapter does not specify any particular water accounting system as the most effective, just that an effective water accounting system would be needed to provide the necessary data for reporting in ways that will help to avoid or resolve conflict.

General Purpose Water Accounting, developed in Australia, is contemplated as a system that can be used to provide the necessary data to aid decision-making. General Purpose Water Accounting is a communication tool about the functions and responsibilities of a water report entity, designed to inform users about how water resources have been sourced, managed, shared and utilized during the reporting period. By doing so, a key objective of the system is to enhance public and investor confidence in the amount of water available, allocated, traded, extracted for consumptive use or removed and managed for environmental and other public benefit outcomes.

The chapter explores the risks that arise from the use and management of water and approaches to mitigating these risks and the conflicts that may arise. Throughout the chapter, the unit of analysis referred to could be a single firm, an industry, economic sector or the state itself.

UNDERSTANDING WATER AS A RISK

Work done by the Intergovernmental Panel on Climate Change (IPCC) has indicated that by 2050 greenhouse gas impacts will cause twice as many areas of the planet to enter into conditions of water stress as those that will be pushed into greater water abundance (Chang 2009). By 2025, estimates indicate that 1.8 billion people will be living in areas with less than 1000 m^3/yr^{-1} of water (defined by Falkenmark 1989a, 1989b and Falkenmark and Lindh 1993 as absolute water scarcity), and two-thirds of the total global population will be living in areas with less than 1700 m^3/yr^{-1} of water (defined by Falkenmark 1989a, 1989b and Falkenmark and Lindh 1993 as water-stressed). For firms, industries or nation-states with growth depending on a given quantity and quality of water for its productive processes, there is a compelling argument that water scarcity will be a driver of conflict in the near future.

In response to the global economic crisis, the Norwegian government made a landmark decision that the publicly listed companies in its pension fund portfolio would henceforth be required to meet certain defined minimum standards of water risk reporting for continued inclusion in the portfolio (Chang 2009). One of the first institutions to respond was JP Morgan Chase, reporting that a shutdown of Texas Instruments or the Intel Corporation semiconductor manufacturing facility due to erratic water supply could cost US$200 million in any given quarter (Klop and Wellington 2008; Chang 2009). Running concurrently with this work in Norway and the US, work by Professor Arjen Hoekstra and his team in the Netherlands reached maturity at about the same time. Prompted by Professor Tony Allan, the 2008 Stockholm Water Prize Laureate and inventor of the concept of virtual water, water that is embedded in any product or service (Allan 1996, 1998, 2002; Allan and Karshenas 1996), Hoekstra quantified global flows of virtual water for the first time, thereby coining the concept of a 'water footprint' (Hoekstra 1998, 2003; Hoekstra and Hung 2002; Earle and Turton 2003; Chapagain and Hoekstra 2004).

Recognizing that the global financial markets were now changing fast in terms of their appetite for risk, SABMiller (SABMiller and World Wildlife Fund 2009) decided to adopt the water footprint concept and embark on an internal learning process whereby they quantified and accounted for all of the flows of water in their global beer-brewing business interests. Following the publication of the SABMiller report, a leading coalition of investors and environmental groups interested in sustainability published a formal report that started to crystallize the concept of water as a risk (Morrison et al. 2009). Further, the Association of Chartered Certified Accountants (ACCA) began mobilizing its membership with a view to developing a formal response from the accounting profession (ACCA 2009).

Having been commissioned by clients in the South African financial services sector and tasked with helping them to understand the implications of this global trend, Dr Anthony Turton has engaged with a range of financial analysts and has defined eight generic types of risk that can be applied to water. These risks are value chain risk, physical risk, financial risk, operational risk, political risk, regulatory risk and reputational risk. The eighth risk relates to scale and is always present in water resource management. Reputational risk is particularly relevant in terms of mitigating risk and may exist at an individual, industry, sectoral, national or supranational level. For example, a water-related reputational risk for a specific mine may be unique to the operation of that mine, in which case sectoral-level risk would be low. Alternatively, the risk may be shared by the whole industry, in which case the risk arises from sectoral factors and sectoral-level risk is high for the mining industry.

TOWARDS A GENERIC MODEL OF WATER RISK

In order to distil out the possible role of water accounting in the mitigation of conflict, it is necessary to develop a generic model of water risk. Risk is defined as the probability of incurring loss or harm (broadly defined), that will invariably have an attached cost. If conflict is to be mitigated, the risks that can lead to conflict need to be understood.

A generic model of water risk is illustrated as a simple input/conversion/output model as shown in Figure 12.1. The model is centred on a 'black

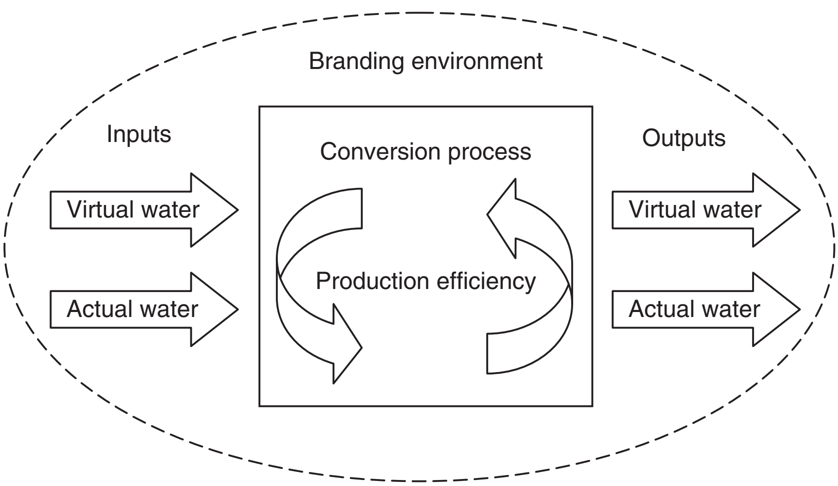

Figure 12.1 Simple input/conversion/output model that depicts a given unit of analysis in the context of water-related risk and thus accounting

box', in which inputs (represented on the left-hand side) are converted to outputs (represented on the right-hand side). The black box is the unit of analysis and can be labelled the 'conversion process' in which productive efficiency plays a pivotal role. On the input side are two arrows, each representing distinct aspects of water. The first is virtual water, representing energy and all of the other inputs such as raw materials that come from the supply side of the overall value chain that sustains the given unit of analysis. The second is actual water used as a productive input. Similarly, the output side has two arrows representing the same things, but in converted form, which reflects aspects of the demand side of the overall value chain. Thus, the product or service being produced has a virtual water component to it, but also an effluent discharge, which in many cases can be a very large component of the overall water balance.

The input/conversion/output model is embedded in a larger entity however, represented by the dotted oval surrounding the entire set of drivers. The quantity and quality of water that flows through the model will be a function of the unit of analysis that the black box represents, and the particular dynamics of a given input/output/conversion process will give rise to a number of specific risks that can generically be called reputational risks. Given the importance of branding in the modern political economy, this larger entity can be thought of as the 'branding environment', and is applied to the unit of analysis in question.

UNPACKING WATER-RELATED RISK

Using this model, the various categories of risk can be discussed with particular reference to the possible role of water accounting in conflict mitigation.

Value Chain Risk

The first and most encompassing form of risk is that related to the value chain, which has two distinct subsets. On the supply side of the value chain, the water-related risk is captured in the water footprint of the various suppliers and can be thought of as upstream value chain risk. Here, there are different local efficiencies in converting a unit of water to a unit of input product (for example, beer inputs include hops, barley and maize). If these crops are grown using natural rainfall, then the water is referred to as green water. However, if the crops are grown using irrigation, then the water is referred to as blue water. Both green and blue water convert a unit of water into a unit of crop biomass, but at different levels of efficiency. Irrigation water is the product of engineered systems, which are costly, whereas rainwater is the product of a natural process of precipitation and thus inexpensive. Another important aspect to the distinction between green and blue water is that of evaporative losses. Irrigation systems are needed only where natural rainfall is scarce and unreliable. Aridity occurs when natural precipitation is less than natural evaporative losses, so the more arid an area the more irrigation is needed, and consequently the less efficient is the ultimate conversion of a unit of water into a unit of crop biomass.

The demand side of the value chain risk is analysed by looking at the effluent discharge of the given production, referred to as grey water, which has to be diluted in order not to pollute the receiving water body. This can be thought of as downstream value chain risk. There is an inverse relationship between the volume of grey water produced and natural precipitation volumes, making the grey water component of production (and the attached risk) larger in more arid areas than it could be in less arid areas.

Lastly, it is important to note that risks do not arise only from local efficiencies. Given the increasingly globalized nature of production and consumption, value chains will often span across international borders. Thus, where any input to production (or indeed final product) is imported, there exists an added unit of analysis to be taken into account. Here, the supply-side risks of the importing country will also be shaped by the local efficiencies of the exporting country/ies. Globalized value chains thus pose a significant challenge to water accounting and the quantifying of risk.

Physical Risk

Physical risk is associated with floods and droughts. It is based on the hydrological regime in which the unit of analysis is embedded and can be thought of as the hydrological foundation of the economy in that specific region of the world. Given that a hydrological regime is driven by biophysical factors, it is closely related to global climate change. As such, much of the data needed for the accounting process to quantify the dynamics of hydrological regimes will be sourced from hydrologists and climatologists, not traditionally thought of as being part of the family of financial risk professionals.

Financial Risk

Financial risk is a cross-cutting category of risk, because in almost all cases, different risks will ultimately translate into financial risk. Financial risks exist at various stages. They are associated with input costs (including the upstream supply side of the value chain), downstream output costs (including costs related to the treatment of grey water) and process efficiency (centred on the three generic elements of any environmental management, namely reusing, reducing and recycling within the unit of analysis). These costs will be directly linked to the pricing of water. Given that water scarcity generally results in the need for water to be transferred from areas of relative abundance to areas of relative scarcity, or for desalination, a specific element of financial risk is energy (Cooley et al. 2006; Webber 2008). The ability to quantify financial risk depends on the accounting for water, as overall financial risk is a function of the quantity and price of water.

Operational Risk

Operational risk involves risks related to the operational activities of the unit of analysis and can be broken down into a cluster of specific risks associated with assurance of supply. If assurance of supply is broadly defined as the probability of a given volume of water, delivered at a specific place and time, at a specific pressure and quality, needed to sustain a specific commercial process, then the overall category can be broken into quantity- and quality-related subsets. If the assurance of supply is lower than that needed to sustain a given economic activity, then risk arises because upstream strategic storage and treatment processes need to be engineered. Failure to engineer this strategic storage renders the enterprise vulnerable when supplies of water are erratic or when water quality deviates from a prescribed norm. Both of these translate into cost of storage and treatment of water. On the downstream side of a unit's operation is the processing of grey water, which can become an integral component of any management strategy to improve efficiency and thus operational risk.

Political Risk

The fifth risk category is political risk. In the broadest sense political risk is the change in social cohesion arising from changes in the overall availability of water. As water becomes scarcer, it is inevitable that some social groups will become excluded, while others remain protected. The effects of water-related political upheaval can be illustrated with the case of Coca-Cola. In 2004, Coca-Cola lost its water licence in Kerala, India, because of political activism against the company in the region (Chang 2009).

Regulatory Risk

Regulatory risk is the risk that regulatory intervention will impose costs on an organization. Corporations require water use licences and as the water resource becomes more stressed, governments may regulate by imposing more stringent standards on those licences or withholding licences from entities that are no longer environmentally acceptable. Considering the example of Coca-Cola above, it becomes apparent that this case could set a precedent to other regulatory authorities across the spectrum of countries in which the franchise operates (Chang 2009). Dr Anthony Turton was involved with a licence application for a pulp manufacturer in South Africa, when the board decided not to expand operations because of a perceived risk in the regulatory environment. Given the uncertainty in future regulatory requirements, the role of water accounting will be vital in lowering or bringing certainty to the perceived water-related risks embedded in the operations of a company or industry.

Reputational Risk

Reputational risk is probably one of the most pervasive forms of risk because in effect all of the other categories can eventually translate into reputational risk if left unmanaged. An example of unmanaged reputational risk is acid mine drainage (AMD), a significant problem in South Africa (Turton 2009, 2010). If AMD is not sufficiently managed, the damage to the reputation of the polluting mine operators could be such that major portfolio managers will start to divest from those specific companies, driven by the perception that this embedded risk makes the stock unattractive. Typically it is where reputation is at stake that corporate social responsibility resources would be invested by the company at risk, because this is one way of mitigating reputational risk. Accounting for the water involved in issues threatening reputation will be vital in both devising and implementing solutions, and to alleviating the fears of investors and stakeholders or at least providing them with information to better understand water-related reputational risk.

Industry or Sectoral Risk

Industry or sectoral risk is defined as the accumulation of risk from a number of individual enterprises that cascades upwards to a sector or to represent the collective risk of a given industry within that sector. In essence, risks pertaining to an industry become part of the profile from which regulators would eventually seek to balance national- or state-level water budgets by assessing the costs/benefits of a given industry or sector within the context of the larger unit of analysis (national or state).

WATER ACCOUNTING, CONFLICT AND RISK

Using the above risk classifications, the role of water accounting in better understanding conflict can be explored. The question arises: where is there the greatest likelihood of conflict occurring over water?

Conflict is a concept best understood as being a spectrum of events, rather than a simple binary condition. This spectrum ranges from armed conflict between states, through hostile engagement via diplomatic or other channels all the way to different forms of peaceful engagement ranging from simple non-hostility to higher levels of cooperation found in jointly managed systems (Hamner and Wolf 1997).

Armed conflict between sovereign states over water is extremely rare, and when it has occurred it is almost exclusively associated with the Middle East, with the majority of cases involving Israel in one way or another (Gleick 1994; Wolf 1998). In Chapter 13, Allan deals with the role of water accounting in international dispute resolution. Empirical evidence shows that where conflict does occur, it is mostly at the sub-sovereign level (Ashton 2000) where the flow of water is under the control of a given sovereign entity. In countries confronting water scarcity there will inevitably be conflicting demands for the resource. These conflicting demands include intersectoral issues (for example, cattle farming versus agriculture), class or legacy issues (for example, rich versus poor), upstream–downstream issues or issues related to rights versus needs. The risk to corporations or the economy is a distinct subset of the sub-sovereign condition.

The risk categorization articulated above is used to illustrate how water accounting, through the provision of the necessary information, will aid in the decision-making of firms and policy-makers in the face of conflicting demands on water.

ACCOUNTING FOR WATER AND THE RISK OCTAGON: CONFLICT MITIGATION

In any analysis, the first step is to isolate specific issue areas that have the potential to cause conflict. In the absence of empirical data, a workshop of experts or opinion leaders can be convened, and by means of facilitation

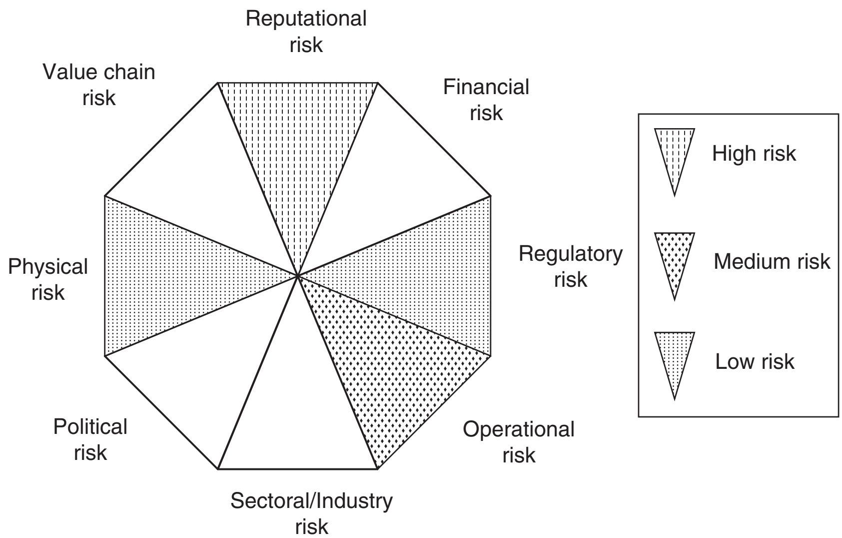

Figure 12.2 The risk octagon

Table 12.1 Tier 1 risk assessment: criteria for risk classification

Risk Category	Criteria for Classification
High	Risk is unknown or being ignored
Medium	Risk is partially known with management aware of it and starting to take it seriously
Low	Risk is known and actively being mitigated

they can be asked what the likelihood of risk in a given category will be, using a traffic light approach (red for high, amber for medium and green for low risk) for the unit of analysis being undertaken (for example, corporation, sectoral, provincial, state or national). This can then be transposed onto what has been termed the risk octagon, which is presented in Figure 12.2.

The risk octagon is a simple rendition of the profile of a given unit of analysis and is used as a Tier I risk assessment. A representative sample of experts can be used to classify the risk profile of the unit of analysis as high, medium or low (as shown in Figure 12.2). The criteria for the classification are explained in Table 12.1. Categorization into high, medium and low risk also implies the need for benchmarking each category of risk, with a view to establishing a baseline against which risk can be categorized. The

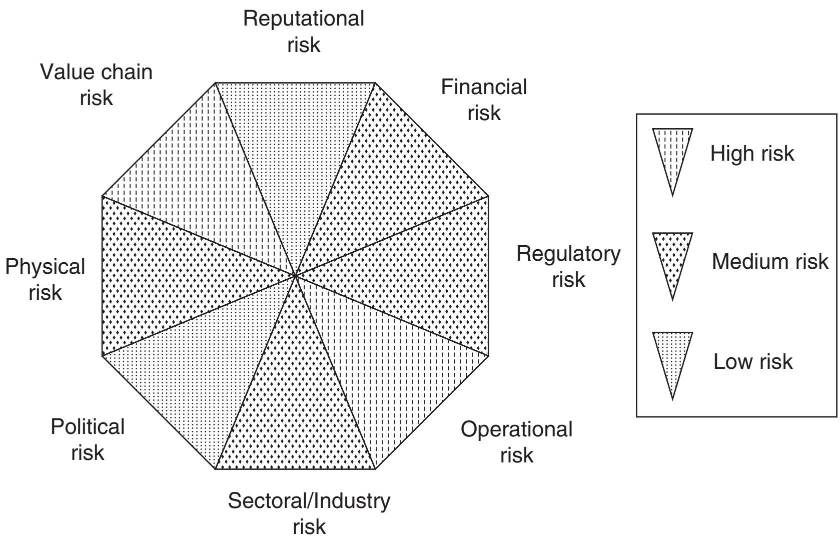

Figure 12.3 Risk profile of SABMiller (South Africa)

risk octagon is applied to both a firm and an industry to illustrate that the methodology transcends scale.

Tier 1: Firm Level

The role of water accounting in mitigating sub-sovereign conflict is illustrated through a firm-level application to SABMiller, a multinational listed company. It is important to note that SABMiller's risk profile, as depicted in Figure 12.3, differs by production location depending on regional hydrological characteristics. For example, the risk profile for a location will be influenced by the relative water scarcity/abundance and the use of green versus grey water in irrigation.

With regard to downstream risk, the SABMiller case is illuminating: the overall water footprint of beer produced in South Africa is a staggering 346 litres of water per litre of beer produced (155 litres found in the upstream value chain risk portion of the overall equation, plus 191 litres in the downstream value chain risk portion) (SABMiller and World Wildlife Fund 2009). This figure indicates that the SAB model is highly sensitive to value chain risks, specifically input-related risks within the virtual water component of the model presented in Figure 12.1, but also within the effluent discharge from the conversion process.

A litre of beer produced by the same process in the Czech Republic uses

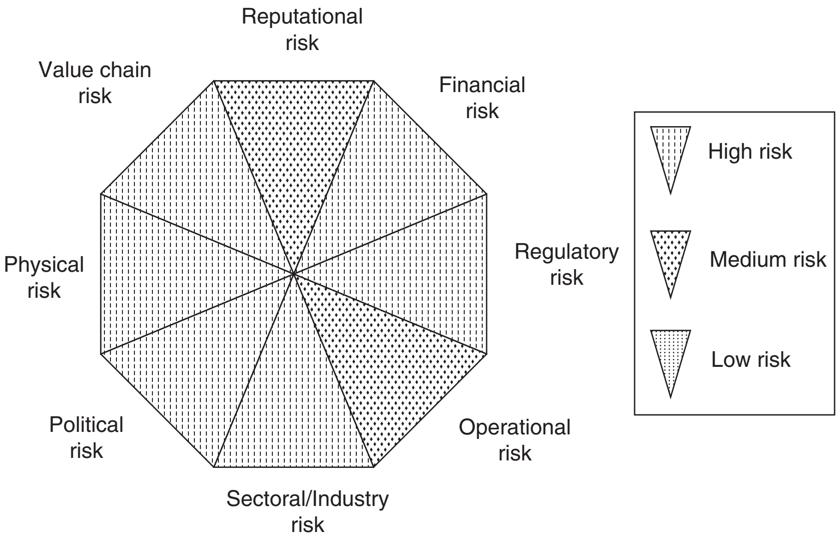

Figure 12.4 Risk profile of the South African agricultural sector

only 45 litres of water in the upstream value chain. The reason for this efficiency differential is related to the virtual water component on the input side of the model. Operational risk and value chain risk are therefore high. By quantifying these risks, the remainder of the risks (besides sectoral) are mitigated through an awareness of where water supply risks are/may appear in the future and the signalling to investors that all risks have been declared.

Tier 1: Industry Level

Figure 12.4 shows the risk profile of the agricultural sector in South Africa, which accounts for 62 per cent of the country's national resource. Given that 97.3 per cent of South Africa's streamflow had already been allocated by 2004, an era of competition over the allocation of water resources for various productive activities exists. The question that arises is how such a water-guzzling industry fits into a water-constrained economy. The sector faces high risk in six of the eight risk categories previously discussed. High value chain, sectoral and physical risk stem directly from pending water stress, while political, financial and regulatory risks are indirect risks associated with how governments may choose to regulate or incentivize the industry. Financial risk also includes the possible divesting of investors in the face of uncertainty. Medium risk in the reputational and operational categories stems mainly from the fact that South African farmers are aware of these risks and how to mitigate them.

Tier II: Water Accounting

Using the Tier I assessment as a guide, it is possible to hone in onto the areas of high risk and start to quantify data underpinning these areas. This quantifying process, the second level of analysis, can be thought of as a Tier II risk assessment, and is based on more empirical data focused only on the areas of high risk. General Purpose Water Accounting, as an example, would present Statements of Water Assets and Liabilities, Changes in these Water Assets and Liabilities, Statements of Physical Water Flows and an Assurance Statement (WASB 2019) of a given water report entity, which would essentially provide the data needed for Tier II assessment. In this quantifying process a crude benchmarking system would need to be established (against which to define the level of risk), to be refined over time. Water accounting could play a key role in systematizing the recording and subsequent reporting of data related to the following specific data streams:

1. What will the impact of global climate change be on the driver? Would it exacerbate the problem or dilute the problem?
2. What will this driver do to latent conflict already found in society? Will it magnify it or will it diminish it?
3. What are the data that would be needed by government and other key players in order to track the unfolding dynamics of conflict in a way that is both credible and useful?

In the case of SABMiller, Tier II output relating to the value chain and operations of their production process would be used as a tool for strategic decision-making. From a national perspective, in both examples decision-makers could start to develop sectoral- and industry-level risk profiles, focusing specifically on the sectors and industries that are the most relevant to the particular political economy in which the analysis is being undertaken. The resulting data and quantifiable risk profiles can be regarded as the first attempt to use water accounting as a tool for decision-making and thus the mitigation of conflict. The reader should notice the implications for sustainability: the process of risk mitigation on a firm level implies adaptation to water efficiencies; and on a sectoral, industry and national level, risk mitigation implies the informed allocation of water through the use of incentives and regulation.

CONCLUSION

There is a compelling argument for the benefit of comprehensive water accounting because it aims to provide comparable and relevant information via the quantification and reporting of water flows and stocks. This chapter's analysis examines the sub-sovereign level, an environment where state sovereignty is seen to be supreme, which means that water sector reform would happen only when various key drivers coincided (Turton 2002). These would include things such as political will, legitimacy of government, perceptions of social justice and a normative framework that seeks the greatest good for the greatest number. Extreme events such as droughts and perturbations to distribution of water resulting from climate change would provide windows of opportunity for reform. Sustainable reform that avoids conflict, however, would need to be informed reform on behalf of a firm, industry or government. Water accounting has a role to play in providing water information to inform decision-making.

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13. The role of a water accounting system in the avoidance and resolution of international water disputes

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INTRODUCTION

During the early years of the twenty-first century, various global initiatives have been progressing in parallel with the development of water accounting systems to propagate uniformity of standards, nomenclature and data collection methodologies related to water information. The concerns that have prompted such progress, for example a desire to facilitate and streamline integrated planning and management and the need for improved communication and transparency, have for many years also been addressed in the agreements that States[1] have negotiated in order to manage transboundary watercourses, with varying degrees of success. Such agreements function to some extent as dispute management tools,[2] partly through these efforts at harmonization, and also because they set out the rights and obligations of the parties to them and thus help to define the boundaries of acceptable State practice. They may also contain details of the procedures to be followed in the event that differences arise between the parties, and potentially the mechanisms that will govern situations where a dispute cannot be avoided.

The aim of this chapter is to assess the specific role that a water accounting system, such as General Purpose Water Accounting (Water Accounting Standards Board 2010), may play in inter-State dispute avoidance. In doing so, the chapter identifies those principles of General Purpose Water Accounting that are shared with existing treaty[3] practice and the broader principles of the law on international watercourses. It then evaluates the relative importance of these principles in avoiding international water disputes so that a clearer understanding of the potential role of a water accounting system can be teased out. It goes on to assess the potential role that a water accounting system could play in the resolution of transboundary water disputes.

THE WATER ACCOUNTING CONTEXT

The focus of this chapter will be on General Purpose Water Accounting, a system that has come to prominence in Australia following the advent of the National Water Initiative (NWI). The NWI is a major reform that seeks to transcend the management and regulatory approaches of the individual state governments, and to harmonize these systems in a way that optimizes the environmental, social and economic outcomes. It is primarily concerned with detailing water sources and uses (including environmental demands) and showing inflows and outflows to and from particular hydrological systems or organizations. One of the objectives of the NWI is the development of 'water accounting which is able to meet the information needs of different water systems in respect to planning, monitoring, trading, environmental management and on-farm management' (Council of Australian Governments 2004, para. 23). More specifically, one of the key elements of the initiative relates to water resource accounting (as opposed, for example, to sector-specific or environmental water accounting), which aims 'to ensure that adequate measurement, monitoring and reporting systems are in place in all jurisdictions, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recovered and managed for environmental and other public benefit outcomes' (ibid. 2004, para. 80).

General Purpose Water Accounting reports are recommended to be prepared by water report entities with the objective of providing information useful for making decisions about the allocation of resources (Water Accounting Standards Board 2010). The NWI sees particular value in the role of measurement, and by implication accurate data collection, in areas '*where there are disputes over the sharing of available water*' (ibid. 2004, para. 86; emphasis added). The National Water Account, which must be prepared and published by the Bureau of Meteorology (Water Act 2007, s. 120), is intended to function in part as a collation and consolidation of the water data produced at multiple institutional and geographical levels and to present this in a standardized format (Bureau of Meteorology 2010, pp. 9–10). While Australia's General Purpose Water Accounting approach is national in its current application, there may also be scope for its use at the international level.

DISPUTE AVOIDANCE

Methodology

Exchange of information and data relating to an international watercourse between its riparian States is beneficial, and this is confirmed in both practice and in literature. Bourne (1972) states that ‘knowledge about the basin promotes co-operation between states’ (p. 22), and regime theory appears to support this. This suggests that States may progressively develop their cooperative activities through learned behaviour with the implication being that regular data exchange may create the basis for increasing collaboration (Toope 2000) and by extension, trust. Furthermore, an argument has been made to the effect that such regular exchange of data may in fact be closely linked to States’ fulfilment of their obligations to use only an equitable share of an international watercourse (McCaffrey 2007).

The desire for objectively validated and verifiable data is evident in existing transboundary watercourse agreements that address issues of data exchange, uniformity of collection techniques and data collation, often in the context of the functions of a basin or joint organization.

Dispute avoidance refers in part to what might be called the compliance mechanisms that States utilize in an effort to avoid the formality, cost, publicity and lengthiness of judicial resolution (Wouters 2003), ensuring compliance with treaty terms in order to keep it alive rather than penalizing breaches (Birnie et al. 2009) with the consequent potential deterioration in relations. It might also include escalation provisions with respect to the procession of a grievance through technical experts, for instance, to diplomatic channels and on to full-blown judicial or arbitral determination. These procedures are on the parties, and indicate both a tacit recognition that States may not always act in the best interests of a basin as a whole, and a faith in the value of the law as represented by the treaty. In fact, from an analysis of existing state practice, McCaffrey (2003) concludes that ‘the presence of a functional treaty . . . seems to decrease the severity of water problems. . . . and thus resulting disputes’ (p. 49).

The other aspect of dispute avoidance is the differentiation between the more general hostilities reflected in ‘conflict’ and the more specific disagreement being pursued in a ‘dispute’, the latter being a manifestation of the former (Collier and Lowe 1999).[4] If the foregoing analysis is correct, it should be possible to have a watercourse treaty between parties who are generally in a state of more or less non-violent conflict, but where disputes are avoided through procedural treatment of grievances.

We are, however, concerned not with the procedures for dispute avoidance in a treaty, but only with those elements intrinsic to dispute avoidance or relationship management that are relevant to water accounting. As data exchange is central to this, McCaffrey's point that regular communication between co-riparians is not only key to the maintenance of an equitable regime, but can also assist with dispute avoidance is highly relevant (2007, p. 480).

Consequently, assuming that treaties can reduce, and by implication avoid, disputes, and accepting that there are elements common to both water accounting and to the issues dealt with by the terms of treaties and by international legal principles, it should be possible to assess the success or otherwise of those shared elements in treaties in such a way that the potential role of water accounting in dispute avoidance can be more clearly elucidated. From the foregoing, those shared elements, which will form the basis for the analysis below, include the following:

1. *Data exchange*. States will be bound not only by the provisions of relevant agreements on watercourse management and related matters, but also by the relevant principles of international law. The assessment below addresses each of these following an outline of relevant customary international law, drawing on State practice. It also outlines institutional frameworks with respect to data management, along with relevant compliance regulation and escalation procedures.
2. *Harmonization of nomenclature and collection methodologies*. Uniformity in data collection methods and harmonization of nomenclature are intimately connected to improving data exchange. However, it is important to note that the harmonization of nomenclature is in some ways less important than uniform collection methodologies, as the former often needs only the application of the appropriate conversion multiplier where units differ across jurisdictions. Variations in methodologies may, conversely, be enormously complex to align.

Data Exchange

Although the UN Convention on the non-navigational Uses of International Watercourses (UNWC) (UN 1997) is not yet in force, it encapsulates and sets out the basic substantive principles of international law on States' rights with respect to international watercourses. Most notable among these are the principles that States are entitled to use international watercourses in an equitable and reasonable manner,[5] and the obligation imposed on States to provide notification of planned measures that are likely to have a significant impact on one or more co-riparians (UN 1997, art. 11(1); see also Rieu-Clarke 2005, p. 138).

In addition, art. 9(1) of the UNWC requires riparian states to regularly 'exchange readily available data and information on the condition of the watercourse', including hydrological, hydrogeological and meteorological data, and although this may not be a rule of customary international law, it has been argued that it is merely a manifestation of the underlying obligation on States to cooperate (McCaffrey 2007). McCaffrey's view is that this obligation is in fact a key element in the fulfilment of an equitable and reasonable balance of transboundary water resources between basin states. Finally, States are broadly obliged to 'employ their best efforts to collect and, where appropriate, to process data and information in a manner which facilitates its utilization by the other watercourse States to which it is communicated' (UN 1997, art. 9(3)).

This highlights the need, addressed by the General Purpose Water Accounting system, for data provision and its receipt to be mutually compatible. The UNWC emphasizes the feasibility of data collection, the use of best efforts and the relative concept of reasonableness, underlining the fact that in many international basins the economic capacity of riparians to set up and maintain comprehensive monitoring systems will vary, and this will have correlative impacts on the potential for application of water resource accounting over the entire watercourse.

Data exchange provisions are not uncommon.[6] India, for instance, is party to bilateral data-sharing arrangements of varying degrees of formality, from the Memorandum of Understanding-based expert-level mechanism in relation to the provision of flood data from China,[7] to the obligations under its agreements with Pakistan[8] and Bangladesh[9] on the Indus and Ganges rivers respectively. Both the latter agreements are regarded as relatively effective conduits for data transfer, using the medium of technical experts rather than diplomatic contacts. In the case of the Indus, escalation procedures are in place that attempt to keep disagreements away from politicians and the judiciary as far as possible.[10]

In basins where multilateral agreements are in place, such inter-party data transfer arrangements are also used. The Lake Victoria Basin Protocol[11] follows the wording of the UNWC with respect to regular data exchange between the parties (arts. 24 and 33), but the basin Commission, like that of the Tripartite Permanent Technical Committee (TPTC) on the IncoMaputo[12] (IncoMaputo Agreement), does not function as a central data repository in the way that, for example, the Secretariat for the International Convention for the Protection of the Danube River[13] does. In common with the latter, data sharing is centralized on the Mekong, where the four downstream riparians have established specific procedures for data and information sharing, under the auspices of the Mekong River Commission Secretariat.[14] In addition, the establishment of joint bodies with responsibility for the collection, compilation and evaluation of data is required under the Helsinki Convention[15] in the United Nations Economic Commission for Europe (UNECE) region. The Danube situation is almost unique here insofar as it includes in its data exchange requirements the national water balance for inflows and outflows.

The consolidation of data within a centralized basin institution might be regarded as most closely resembling the responsibilities of the Bureau of Meteorology (BoM) in the Australian situation, especially in a context where all basin States are parties to the relevant watercourse agreement. In addition to these basic information exchange provisions, a few agreements go one step further towards the water accounting ideal, and impose obligations on the parties to make data available to the general public at the national level. Notable examples include the IncoMaputo Agreement (art. 12(8)) and the Albufeira Agreement governing the major rivers between Spain and Portugal (art. 5).[16] The latter agreement in turn reflects the terms of the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters[17] (the Aarhus Convention), especially in relation to the exceptions justifying withholding of information. The reasons include national security and the international relations of the parties (Albufeira Agreement, art. 6) – exceptions that are shared with the Indus,[18] although with respect to the latter, there is no obligation imposed upon the Permanent Indus Commission to publish the data it processes. While the wording of the exceptions may be similar in each case, the extensiveness of the interpretation will surely depend on the relations between parties.

Although States may be bound to share data with co-riparians at government level, additional problems may interfere with or complicate the logistics of this communication. With respect to databases for example, the European Union affords two levels of protection to database creators[19] through the Database Protection Directive. Where the database is deemed to have been developed through the intellectual creativity of the author, copyright control is imposed (art. 3). In addition, the sui generis right provides authors of non-public databases with a degree of control where there has been a substantial investment made in the generation, verification or presentation of the contents (arts. 7 and 8; see also Chen et al. 2008). These controls inhibit the extent to which users of the data can use them, and concerns have been expressed by bodies such as the World Meteorological Organization that the principle is inimical to the free flow of scientific information.[20]

Harmonization of Nomenclature and Collection Methodologies

Current State practice suggests that achieving uniform data collection methods between jurisdictions is afforded less importance than simple data exchange. There are exceptions, however, where the value of such efforts is recognized at the international and regional levels, especially with respect to the development of joint monitoring programmes. In Europe, for example, the Water Framework Directive demands that appropriate monitoring programmes be established for the assessment of water status,[21] along with technical specifications and standardized methods to enable the analysis and monitoring of water status.[22] Also in the broader European context, the Helsinki Convention demands that parties 'harmonize rules for the setting up and operation of monitoring programmes, measurement systems, devices, analytical techniques, data processing and evaluation procedures' (art. 11(4)).

These European principles are focused primarily on the utility of joint monitoring programmes for planning purposes. In terms of negotiated agreements in this region, the International Convention for the Protection of the Danube River actually recognizes a concept of the water balance very close to the General Purpose Water Accounting approach. It is defined in art. 1 as referring to the 'relationship characterizing the natural water household of an entire river basin as to its components', that is, its inputs and outputs. This forms the basis of its cross-border monitoring, and art. 9(3) provides that the parties will establish a harmonized methodology for measuring the national water balances for each basin state.

The basic assumption underlying this approach is that because the accurate calculation of a national water balance will depend on having details of the input from upstream states and the output to downstream riparians at respective borders, the so-called connecting data at those points should be agreed by all. This therefore logically requires a harmonized methodology. Summaries of those data are required for elaborating downstream balances and must be provided to the Secretariat for the convention (Helsinki Convention, art. 1), which compiles the data and uses it to populate its basin-wide database, DANUBIS. While the Danube position does not emulate the water accounting system in its entirety, its concentration on deriving a basin-wide understanding of the uses of the river using national water balances is closely related to the latter.

In the Mekong context, the importance of the Mekong River Commission Information System (MRC-IS) is highly relevant to planning and decision-making.[23] The MRC-IS is coordinated by the Mekong River Commission (MRC) Secretariat, the role of which is essential here, as it coordinates and manages a data-gathering network in four countries in a way that is required to be efficient, transparent and cost effective.[24] Uniform data collection techniques, and compatibility between national systems and the overarching MRC-IS are therefore potentially critical in this context if these principles are to be achieved. The absence of the other two riparian States, Myanmar and most especially China, from the Mekong Agreement and thus formally from the MRC-IS, is therefore problematic in this context because neither data collection techniques nor transfer are in place.

The parties to the IncoMaputo Agreement are specifically obliged to ensure that hydrological, geohydrological and water quality data, among others, are 'homogeneous, compatible and comparable' (art. 12(7)). The Agreement goes as far as to identify the physical monitoring stations from which data will be accepted (Annex 1), and sets out in detail the allocation of available flow levels and the consequences for use priority and environmental allocations in the event of particular flow conditions being in place.

DISPUTE AVOIDANCE CONCLUSIONS

It appears, then, that there are two broad bases for the value of data collection. The first suggests that where no watercourse agreement is in place, co-riparians would be well advised to exchange basic data on mutual rivers simply in order to allow them to assess whether they are making use of their respective equitable and reasonable shares. The second rationale posits that this joint activity will lead to closer coordination through habit and hence to a reduction in the number of disputes between watercourse States. In fact, it is apparent from the Indian examples that States may continue to exchange data with countries irrespective of an otherwise acrimonious relationship.

While there is an awareness of the value of having harmonized collection procedures and techniques, there is a sense that the strongest expressions of this occur in the context of centralized data collection and joint bodies. It also seems that what may be the logical extension of national data exchange, the publication of that data to the interested public, is also encouraged in this context, although the IncoMaputo and Lake Victoria basin agreements indicate that this is possible even without a joint body.

There are challenges, however, in basins exhibiting significant economic variation between riparian states, especially where the upstream states are the most economically disadvantaged, because the data that States are obliged to exchange need only be those that are feasible in their straitened circumstances. Given that it is in the downstream State's interests to receive data that are as accurate and mutually compatible as possible, downstream states might logically invest in upstream infrastructure, something that has already happened in Bhutan, where India has funded an entire flood forecasting network for their shared rivers (Government of India, Ministry of Water Resources 2011).

DISPUTE RESOLUTION

If, despite the best efforts of riparian States to avoid an escalation of a grievance to a dispute, there is a deterioration in their relationship such that they initiate full judicial or arbitral proceedings, the potential role of water accounting would change significantly.

It is clear from international jurisprudence that although protestations regarding the quality of data may protract negotiations for a watercourse agreement, data quality is neither an important determining factor in resolving disputes relating to transboundary waters, nor a crucial element in the precipitation of judicial proceedings.[25] The International Court of Justice (ICJ) will assess the cases presented by parties to an action against the standard of equitable utilization,[26] or against the terms of any relevant international agreement where, for example, volumetric shares have been established. The UNWC, in addition to recommending joint bodies for cooperation at basin level (arts. 12 and 24 respectively), takes as its default position in the event of an inter-riparian disagreement, the appointment of an impartial fact-finding commission in an effort to avoid the outbreak of a full dispute.[27] Clearly, the quality of the data supplied to the commission under art. 33 (7) will be of concern to the parties. Where the data quality is accepted by the parties, the decision of the fact-finding commission, or judicial tribunal for that matter, will be based on the *interpretation* of that data (Pulp Mills 2010, para. 7). Simple agreement on the data between the parties would therefore have the probable consequence of reducing the deliberation period for the fact-finding commission because it would not be required to evaluate different national data sets and the methodologies used to derive them. Fact-finding commissions have historically played a significant role in preventing the escalation of disputes.[28]

Whether a State has or has not overstepped its legal entitlement to the waters of a transboundary watercourse will depend upon the facts, those facts being derived from evidence presented by the parties to the presiding judges.[29] Where volumetric or percentage shares have not been put in place by a watercourse treaty, the court will evaluate a State's equitable share based on an assessment of relevant factors, and examples of these are set out in art. 6 of the UNWC. They include, for example, the hydrology of the river, its physical and ecological environment, national, social and economic contexts, and the availability of alternatives (UNWC, art. 6). Although none of these factors has inherent priority, special regard must be given by the court to relevant vital human needs (UNWC, art. 10(2)). If an agreement is in place between riparian States, it may be that an apportionment of the related waters between those States has been included. This is the case, for example in the case of the Amu Darya, where two of the riparian States have apportioned the entire flow of the river equally between them.[30] The IncoMaputo Agreement also contains detailed flow regime provisions in Annex I. In the context of any form of water accounting, questions therefore arise with respect to its possible role in aiding the determination of the legal entitlement (whether equitable and reasonable or specified in a relevant agreement) and in relation to its quality as evidence with respect to the standard of proof applied.

DETERMINATION OF LEGAL ENTITLEMENT

The information contained in General Purpose Water Accounting reports is intended to 'improve understanding of how water resources are sourced, managed, shared and used' (BoM 2011). The raw data it produces hopefully allows for greater transparency and better management of the resource, with decision-makers retaining the ability to assess the relative relationships between water use, economics and the environment.

If such a system were in place with respect to water between States, with correlative harmonization of standards, nomenclature and collection methods, and most crucially, open exchange of data, States would have a far better idea as to how the resources of an international watercourse were actually being used by its various co-riparians. As noted above, this exchange of data between watercourse States may be useful if a State is to assess if its use of watercourse is equitable because it will be able to see how much other countries are using and for what uses. This would allow it to regulate its own uses accordingly. The fact that a grievance over the level of a State's use of a river has made it to judicial proceedings would imply that the preemptive assessment of the equitable shares of riparian States has been unsuccessful. This would not be a surprising outcome in some ways, as States cannot hope to apply the same weights to all relevant factors as the ICJ, for example, would. In any case, a State's equitable share of an international watercourse would necessarily be fluid as population, climate and uses change over time.

Although the General Purpose Water Accounting approach might be of great relevance to assessing if a State has exceeded its volumetric entitlement to the water of a river as set out in a treaty, it is difficult to see how it would aid determination by a court or tribunal of a State's equitable share. The relationship between water use statistics and the other factors that would come into play in the judicial decision-making process would remain uncertain. However, the data provided by a water accounting approach, such as General Purpose Water Accounting, may potentially be more useful with respect to the quality of evidence available for judicial consideration.

STANDARD OF PROOF

A court will come to a decision based on the evidence before it, presumably including the data collected by the parties to the action. However, the standard of proof applied in international tribunals is not well defined, with commentators inferring varying standards from 'preponderance of evidence' (Kazazi 1996, pp. 347–8), to 'clear and convincing evidence' (Jones 2009, p. 175)[31] and 'balance of probabilities' (Brower 1994, p. 48). Ultimately though, international courts have 'always avoided a rigid rule regarding the amount of proof necessary to support the judgment' (Velasquez Rodriquez case in Kazazi 1996, p. 351), with at least one commentator suggesting that the standard will to a large degree depend on the legal backgrounds of the judges (*Durward* v. *Sandifer* (1939) in Brower 1994, p. 47).

Where a water accounting approach has been taken by contesting parties, the quality of the water data to be put before the judges will presumably be reasonably good given the technological and monitoring demands of the approach and the fact that both parties have agreed on the data, a benefit that has been regarded as helpful in the context of fact-finding in the past (Jones 2009, p. 176). This will only be true with regard to the period during which water accounting has been practised by the States, so questions may still be raised with regard to the longer-term situation. This may be important as the use patterns may vary between dry and wet periods and considerable difficulties can arise in trying to demonstrate what the 'normal' condition of a river actually is.[32] However, the mere fact that the data relating to water inflows and outflows have been agreed by the parties for a particular period will be of comparatively limited utility because they are likely to constitute only one part of the evidence marshalled in court.

Disputes can be driven by problems with water quantity (on the Nile for example), quality (Pulp Mills case), and flow (the current disagreement over the Kishanganga Dam under the Indus Waters Treaty, for instance), but they can also be driven by grievances over existing water use patterns as well as by inequities projected to be caused by planned man-made developments on international watercourses. In these latter cases, key questions will relate to the data projections associated with the new project, their impact on existing water use data and the weighting given to the multitude of other factors that the court will be obliged to consider.

CONCLUSION

Examination of the role of water accounting in dispute avoidance and resolution proceeds from a series of logical assumptions. Political difficulties between States can increase the severity of disputes, and in some cases precipitate them. Data exchange is commonly accepted to be one way to increase the level of inter-State cooperation. In some cases greater cooperation may lead to the formalization of a watercourse agreement, and functional treaties are linked to a reduction in international disputes. It may be that joint bodies are a critical component of such functional treaties. Finally, even if a formalized watercourse agreement is not the result of greater cooperation by States, reciprocal communication may still provide the preliminary basis for States to try to unilaterally determine whether their use of a transboundary watercourse is equitable and reasonable.

The exact role of effective data exchange in dispute avoidance (for example, taking account of measures such as the harmonization of nomenclature and collection techniques that are useful for the streamlining of collection and collation of data) can only ever be nebulous. Except for a very limited number of instances, it is not possible to say how many disputes have been avoided as a result of one particular factor. In those instances where potential differences have been resolved through, for example, reference to expert bodies, a number may be ascribed, but even here one must be circumspect because such numbers may still mask the impact of having quotidian data communication managed by technical experts who can iron out difficulties before they even get to the referral stage. What is clear, however, is that core features of General Purpose Water Accounting (data exchange, harmonization and transparency) are also being used at the international level as part of efforts to manage watercourses, to avoid disputes and manage differences.

The relative importance of these features differs depending on how advanced the disagreement is. Water accounting principles are in some ways less important at the resolution stage simply because of the nature of the balancing of factors that a tribunal would necessarily have to perform. Such decisions are based on an evaluation of equity given the individual circumstances of each case. The accuracy of the data, and the extent to which the parties accept it, will be an element in the assessment of the facts of the dispute, as was indicated in the Pulp Mills case. It seems likely that this role will be comparatively minor, given the proportion of evidence that the agreed water use data will constitute compared to economic, environmental and social data and against the inferences that decision-makers have made from these.

The same is not true at the dispute avoidance stage though, as it seems that the potential role for the harmonized data collection approach proposed in General Purpose Water Accounting is likely to be higher here. That this is indeed the case is reflected in the terms and practice of almost all of the international agreements highlighted above. There is pronounced focus on efforts to harmonize data collection and nomenclature, even although the strength of the supporting terms may vary considerably and in some places a framework akin to General Purpose Water Accounting has in fact been adopted, most notably in the Helsinki Convention and with respect to the Danube. Despite these similarities, there are important reasons to qualify the potential role of a system of water accounting in the dispute avoidance context.

It was suggested above that States may look at data exchange as part of the trust-building facilitated by treaties or as part of a drive to determine their own equitable and reasonable share. Many disputed basins lack effectively functioning agreements governing their allocation and use, however, and in such circumstances data harmonization initiatives lack the support and trust encapsulated in an existing treaty. There may be reason to be cautious about this approach, unfortunately. International efforts to standardize data collection methodologies and terms do not have an illustrious history in this context. The Committee for Hydrology of the World Meteorological Organization has been trying with little success to do so on a global basis for over a decade,[33] and historically States have not naturally shared data well with their political adversaries. The case of Israel and Palestine is salutary in this regard.[34] At the basin level, where action is needed in the first instance, global standards could be useful with respect to the development of virtual water statistics,[35] or in the context of water transfers that are both inter-basin and inter-jurisdiction, although the latter are perhaps less likely to need them.

It is also difficult to agree that by exchanging data, States can at least begin to evaluate their existing use of a transboundary watercourse against their equitable share. Such an exercise would demand very much more data on all relevant factors (social, environmental, economic and physical data, along with information on alternative sources, for instance) and an ability to predict how a tribunal might weigh these against one another. This seems unduly optimistic. The best hope for data exchange in the absence of a treaty is therefore as a means to get States communicating, and this can then be used as the basis for future cooperative activities. This may in fact be the lesson from China's decision to provide flood data to the

Indians, especially as it appears that part of the reason it has chosen to do so is linked to its wish to scotch certain allegations that have been circulating in India. These rumours have suggested that the low flows experienced downstream during a recent dry period resulted from China's over-use of the Brahmaputra river for hydropower production rather than simply from a worse than usual drought.

The other consideration that has not been addressed to the same extent in the international arena is that of transparency. Australia's National Water Account is to be published annually. Similar arrangements in watercourse agreements to make shared data public at the national level are not common – the Albufeira and IncoMaputo provisions are relatively exceptional. It also remains to be seen how the treatment of databases affects international data exchange, especially where a river flows through an economically diverse series of countries where ability to pay for data on the part of one riparian is concomitant with an inability to pay for appropriate national monitoring networks or institutions. The future of a water accounting approach such as General Purpose Water Accounting in such regions may precipitate greater investment in upstream monitoring infrastructure, although delicate questions of sovereignty may be disturbed in the process.

Transparency may cause difficulties in the short term, however, because it would still rely ultimately on inferences made on the basis of less than complete data, and national governments in mutually hostile States will be unwilling to divulge what is perceived to be sensitive information. In the longer term though, in common with more general arguments on transparency, it could provide a mechanism for nationals to hold their governments to account against their international obligations, in a manner similar to that used in the Aarhus Convention (Aarhus Convention Compliance Committee 2011). The institutional context for basin-wide distribution of data is related to this, although international practice appears inconclusive on the subject. A joint basin body may be the best approach in some ways, because it might be best placed to collate data from riparian States and to distribute it in a way that is clear, comprehensive and accurate, a feat that would be more difficult with respect to simple data exchange between multiple riparians. Only then would an impartial basin-wide position be available, and it may therefore be that this is the ultimate lesson of water accounting for the international community. As regards the role of water accounting in international water dispute avoidance, the role of the shared principles of data exchange and the harmonization of nomenclature and data collection appear to be desirable, but to some extent dependent on the presence of other conditions if their utility is to be optimized.

NOTES

1. Consistent with international legal writing, capitalized 'States' is used to denote sovereign countries. Non-capitalized 'states' indicate the constituent states that collectively make a whole country in the federal context.
2. The 'proper function of law is to manage, rather than to suppress or resolve, conflict' (Collier and Lowe 1999, p. 1).
3. The definition of 'treaty' used here will follow that of the Vienna Convention on the Law of Treaties (1969), art. 2(1): 'an international agreement concluded between States in written form and governed by international law . . . whatever its particular designation'. Insofar as they correspond with this definition, the terms 'convention' and 'agreement' used in the chapter will therefore also be synonymous with 'treaty'.
4. The traditional meaning ascribed to 'dispute' in international law derives from the Mavrommatis case, where it was defined as a 'disagreement on a point of law or fact, a conflict of legal views or of interests between two persons' (Mavrommatis Palestine Concessions, (1924)).
5. UN (1997), art. 5.
6. There are information exchange provisions in 92 of the 145 agreements listed by Beach et al. (2000), for example.
7. For available details, see website of the Indian Ministry of Water Resources at http://india.gov.in/sectors/water_resources/index.php; accessed 10 October 2011. More formal flood data-sharing arrangements are in place between Nepal and India; see Salman (2003), at p. 162.
8. The Indus Waters Treaty, signed at Karachi on 19 September 1960 (entered into force 1 April 1960), 419 UNTS 125.
9. Treaty between the government of the Republic of India and the government of the People's Republic of Bangladesh on sharing of the Ganga/Ganges Waters at Farakka, signed on 12 December, 1996 (36 ILM 519 (1997)).
10. Thus far, only one disagreement has been referred to neutral expert under art. IX(2) (a) (with respect to the Baglihar Dam), but it seems that the ongoing debate over the embryonic Kishenganga Dam has finally resulted in the first application to arbitration by the Pakistani side – see *Express India* (2010).
11. Protocol for Sustainable Development of Lake Victoria Basin, signed 29 November 2003, Arusha.
12. Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and the Kingdom of Swaziland for Co-operation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses, signed 29 August 2002 (the 'IncoMaputo Agreement'), art. 12.
13. Convention on Co-operation for the Protection and Sustainable Use of the Danube River, signed June 29 1994, Sofia (the 'Danube Convention'). In force 22 October 1998, infra, para. 2.3.
14. Procedures for Data and Information Exchange and Sharing (in force 1 November 2001), under the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin (in force 5 April, 1995), art. 5(1).
15. Convention on the Protection and Use of Transboundary Watercourses and Lakes (Helsinki), 31 ILM 1312 (1992) UN Doc E/ECE/1267. In force 6 October 1996 (the 'Helsinki Convention'), art. 9(2).
16. Agreement on Cooperation for the Protection and Sustainable Use of the Waters of the Spanish-Portuguese Hydrographic Basin, 30 November, 1998 (entered into force 17 January, 2000), United Nations Treaty Series 2099, 275, art. 5 (the 'Albufeira Agreement').
17. Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, 25 June, 1998, UN-ECE-CEP-43, 38 ILM 517 (entered into force 30 October 2001).

18. For India, see the Right to Information Act 2005, s. 2, 3 and 8(1)(a). For Pakistan, the relevant provisions are contained in art. 19 of the Constitution of the Islamic Republic of Pakistan.
19. Defined as: 'a collection of independent works, data or other materials arranged in a systematic or methodical way and individually accessible by electronic or other means' – Directive 96/9/EC of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases, *Official Journal* L 077, 27/03/1996 P. 0020 – 0028, art. 1(2).
20. An alternative view has been submitted to the World Intellectual Property Organization: in 2002, the report of Yale Braunstein to the Standing Committee on Copyright and Related Rights' Seventh Session, concluded that '[t]he existence of differing approaches to the protection of databases across the developed countries is not likely to be a problem for the developing countries' (p. 27).
21. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, *Official Journal* L 327, 22/12/2000 P. 0001 – 0073, art. 8.
22. In conjunction with the procedure set out in Council Decision of 28 June 1999, laying down the procedures for the exercise of implementing powers conferred on the Commission (1999/468/EC), as amended. See also the INSPIRE directive (Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), OJ, vol.50, L108, especially art. 5, which is concerned with the inter-operability of data sets.
23. Guidelines on Custodianship and Management of the Mekong River Commission Information System, art. 1 (MRC 2006).
24. Procedures for Water Use Monitoring (MRC 2003), 30 November 2003, art. 3, available at www.mrcmekong.org; accessed 10 October 2011.
25. See, for example, Beach et al. (2000, pp. 40–44).
26. Case concerning the Gabčikovo-Nagymaros Project (*Hung* v. *Slovak*), 25 September 1997, 37 ILM 162 (1998), para. 85, for example.
27. Following a period of unsuccessful inter-party negotiations (UN 1997, art. 33(3) (*et seq.*)).
28. See, for example, Jones (2009).
29. Kazazi (1996) says 'the ultimate function of judges or arbitrators . . . is to evaluate the evidence before them in order to make a ruling on the case' (p. 28).
30. Agreement between Turkmenistan and the Republic of Uzbekistan on Cooperation over Water Management Issues (Chardjev, 16 January 1996).
31. Jones would suggest that it may be that there is a qualitative difference here, though, insofar as preponderance of evidence may be appropriate in situations where the court accepts that it is not possible/feasible for parties to pull together all the evidence necessary to prove beyond reasonable doubt. Compare this with the clear and convincing evidence test, as this latter may be more applicable in cases where it appears that full evidence is presented and no question of more evidence being out there.
32. In the USA, the calculation of a river's 'dependable flow' in relation to an interstate equitable apportionment led to much debate in relevant Special Master reports. See, for example, the definition in *Nebraska* v. *Wyoming*, 325 US 589, 620 (1945), where it was deemed to be no greater than the average flow over the previous 15 years.
33. See website of the World Meteorological Organization at www.wmo.int; accessed 10 October 2011.
34. See, for example, Daibes (2004), especially Part V.
35. Note the International Organization for Standardization's current efforts to produce a standard for a product's water footprint under ISO 14046.

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14. Water accounting issues in California

Jay R. Lund

> If you can not measure it, you can not improve it.
> Lord Kelvin

INTRODUCTION

At a general level, accounting provides a formal technical means of implementing a robust framework for managing a scarce resource. More particularly in relation to water and in the presence of water scarcity, it is likely that an absence of an effective system of water accounting to underpin water management will lead to disruptive and chaotic conflicts nationally, or even internationally. Successful water accounting does not eliminate conflict, but it confines water conflicts within a legal and technical framework where they can be more efficiently addressed, with a minimum of chaos. In successful water systems, most water users (households and farms) see only the price of water use and any rules restricting use, and are not actively engaged in water accounting. Water districts, utilities and state regulators do the accounting. The accounting provides retail and wholesale water providers with greater legal and operational certainty on supply availability and costs, as a basis for setting retail prices and allocation policies.

Water accounting, the quantification of flow volumes for financial and water management purposes, dates from at least as far as Roman times (Frontinus AD 97). It is an example of using a rigorous and robust recording and reporting technique to assist in transparent management of a scarce resource. Interestingly, Frontinus also wrote a treatise on land surveying, the accounting of land ownership. The further development of accounting for water descends from the French engineering schools of the 1700s that pioneered quantitative methods to better understand, design and advise on all manner of engineered systems, including water. Today's forms of water accounting also benefit from the business and financial accounting tradition dating from the Renaissance.

Water accounting is needed to enhance the efficiency and effectiveness of the operation of water systems, as well as for overseeing the allocation of water among competing water users and uses. In California, rapid population growth and regulatory pressures to address unmet environmental flow needs have raised the importance of water accounting in recent decades, as agricultural and urban users find themselves with reduced overall supply availability (California Department of Water Resources [DWR] 2010). These pressures are likely to increase with climate change, which will reduce seasonal water storage in mountain snowpacks and could easily decrease the total amount of water available.

Water management innovations such as water marketing, conjunctive use of surface and groundwaters and water conservation and reuse are tools to better cope with this scarcity. But such increasingly sophisticated operations within a complex and extensive water system require more precise coordination, and therefore better accountability and accounting for water. Currently, water managers and regulators often rely on rough water quantity estimates, as state law does not require systematic water use reporting.

This chapter reviews the roles and problems of water accounting in California, and suggests several regulatory and technical approaches to improving the accuracy of water quantification. The discussion is extended to examine how water accounting in California compares with accounting used for other environmental fluids, such as oil and natural gas and potential future roles of computer models to provide a physically coherent and consistent framework for regional water accounting.

PURPOSES OF WATER ACCOUNTING

As indicated in other chapters of this book, the main purposes of water accounting are to reduce conflicts among water users and improve the utilization and management of water. Water accounting can improve water management in several ways. These include:

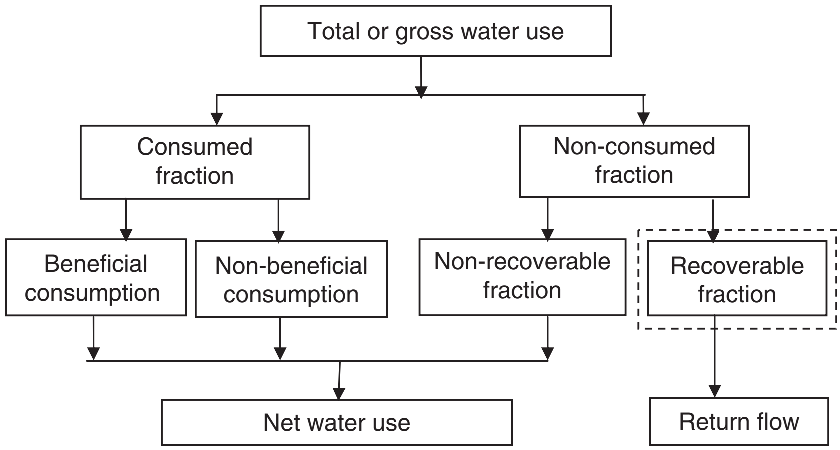
1. Establishing a more precise and accountable quantitative framework for water rights, contracts and agreements to give users and suppliers more certainty regarding the legal and physical availability of water. This formalizes and constrains water conflicts and makes decision-making easier for commitments and investments that manage and develop water supplies.
2. Improving estimates of legal water availability, which allows managers to better understand conditions when commitments and investments should be hedged. Without assurances from an authoritative and

reliable water accounting system, local and regional water decision-makers would be more reluctant to make desirable commitments and investments, either reducing water deliveries from poorly accounted sources when water was usually available or incurring unnecessary expenses to hedge supplies more frequently than necessary.
3. Increasing the flexibility and efficiency of water markets. When water accounting is non-existent, unreliable or not authoritative, this implies that property rights to water are insecure. If property has less legal security, it becomes less valuable in a market, is less operationally reliable, and therefore is less likely to be used efficiently.
4. Improving the application of other water management actions, such as conjunctive use of ground and surfacewaters, water conservation and wastewater reuse. When water accounting is absent or faulty, managers may find they do not receive sufficient additional reliability from such activities. In particular, faulty or absent accounting of the water quantity and rights effects of water management actions can lead to less efficient selection of water management investments.
5. Supporting government regulation, both of water rights and water quality, which often depends substantially on water flows. It is difficult to make users accountable for their use of water without an accounting system.

In California, legal insecurity of water rights in the early years of settlement prevented large-scale water development (Hundley 2000). Only following the 1928 amendment of the state constitution where riparian rights were limited, was there enough legal assurance for extensive large-scale surfacewater development to proceed. In California today, with considerable existing water management infrastructure, demands and institutions, tightening of supplies and increases and diversification of demands are forcing more complex forms of management, such as water marketing and conjunctive use of ground and surfacewaters, which require still greater assurances, requiring more formal water accounting.

PHYSICS OF WATER ACCOUNTING

Accounting for water use differs from accounting for most other physical goods. After water is used, some or all of the water returns and becomes available for reuse downstream. Net water use often is much less than gross use. Irrigation water that infiltrates below the root zone recharges an aquifer and treated urban wastewater discharged into a stream can be reused downstream. This physical ability to reuse large amounts of water



Source: Adapted from breakdowns in Molden (1997); Molden and Sakthivadivel (2006); Perry et al. (2009).

Figure 14.1 Total water use breakdown for physically-based accounting

among users within a region has led to considerable confusion among many concerned with water conservation (Perry et al. 2009). A region can use some of the same river at least twice.

Some more physically-based accounting terminology has been developed in recent years to help overcome this confusion (Molden 1997; Molden and Sakthivadivel, 2006; Perry et al. 2009). The total water used or applied can be divided into a consumed fraction (which evaporates or transpires, leaving the use site as water vapour) and a non-consumed fraction (which leaves the use site in liquid form). The consumed fraction has two components, beneficial consumption (that fraction that typically goes to transpiration for beneficial plant growth) and non-beneficial consumption (that fraction typically going to evaporation from wet soil and water surfaces or transpiration from unintended uses such as weeds). The non-consumed fraction leaves the site where water is applied in liquid form and is divided into a lost non-recoverable fraction (which runs off to a saline water body or infiltrates to a saline aquifer of a deep aquifer from which water is not economically recoverable) and a recoverable fraction (which can be economically recaptured in a stream or aquifer for reuse downstream). These are depicted in Figure 14.1, where the recoverable fraction is highlighted with a dashed box. The recoverable fraction is often called the return flow and the sum of consumptive and non-recoverable losses can be called net water use.

The recoverable fraction of water use or return flow is particularly important for regional water accounting, as it is an additional source of water to the region. If water rights are based on historical gross water use, changes in regional or on-site water management are likely to lead to shortages of physical water undetected by the water accounting system. This is common in water markets where users buy and sell total water use rather than consumptive and non-recoverable water use. This introduces a divergence between so-called real water and paper water in market transactions, with shortages in the system (often to the environment or third parties not part of the market transaction). If a farmer sells the water consumed as well as the water that returns to the stream, and the purchasing farmer, perhaps located upstream, diverts the entire purchase and returns none, downstream users will have less water available than before, without having benefitted from the market transaction. Having water rights and contracts for the combined non-recoverable and consumptive portions of water use (net water use) helps avoid discrepancies between the physical and legal existence of water. However, accounting systems based on net water use do impose practical measurement and estimation challenges.

OVERVIEW OF WATER ACCOUNTING IN CALIFORNIA

In some ways, California is the Wild West of water accounting. Its legal and regulatory framework for water accounting varies greatly with particular circumstances, as summarized in Table 14.1 (Bureau of Land Management 2001). For many types of water use, water accounting hardly exists at all, and in other cases, such as the separation of surface and groundwater rights, water rights accounting violates the physics of water. Post-1914 appropriative surfacewater rights receive permits and are overseen by the State Water Resources Control Board (SWRCB). Older appropriative water rights and riparian water rights (established under English common law) are largely regulated by the courts. Groundwater is mostly unregulated or is overseen loosely by local authorities under state legislation or adjudicated by state courts. Also, large amounts of surfacewater rights are managed by regional, state and federal water projects that hold water rights, but deliver water under contract to more local wholesale and ultimately retail water agencies. So water contracts have a major role in water accounting in California. Finally, water accounting is routinely required by local retail water agencies, selling water directly to end-use customers.

Table 14.1 Water accounting in California

Water Function	Agencies	Form of Accounting
Water rights		
Post-1914 surface water	SWRCB	Permits, annual reporting
Pre-1914 surface water and riparian rights	Courts	Local water masters for adjudicated basins
Groundwater	Courts	Court adjudications and local agreements, local water masters
Water quality	Regional water quality control boards and SWRCB	Water quality monitoring
Planning	DWR	Basin estimates
Contract and agreement enforcement	Water project owner or operator	Field measurements and estimates
Market transactions	SWRCB and DWR	Consumptive use accounting by water right authorizations and DWR conveyance authorities

Surface water rights developed after 1914 are administered by the California State Water Resources Control Board in the form of water rights permits. Pre-1914 rights and older riparian system rights were 'grandfathered' and do not require formal registration or permits with the SWRCB. SWRCB permits typically specify a date for the water right (which establishes its priority in case of scarcity), as well as a quantity, place of diversion, place of use, type of use and any other restrictions. All water use in California is subject to a state constitution section that mandates that all water use be reasonable. All rights holders must generally put water to a beneficial use in some sense. Surfacewater rights permit holders are required to submit reports of actual water use annually, although only 35 per cent of rights-holders report their use on time (SWRCB 2010).

Groundwater rights are managed largely under common law by state courts (Blomquist 1992). Less than 20 groundwater basins in California have been adjudicated, meaning that a judge has imposed or agreed to a division of water rights to the aquifer among the area's water users. For most of California's groundwater, any overlying pumper can withdraw as much as they would like, with the exception of withdrawing water artificially recharged (Kletzing 1988). This lack of formal water rights for groundwater and the near complete lack of accounting and accountability for groundwater withdrawals have forced local governments and irrigation districts to be creative in indirectly regulating groundwater use. A common method of regulating groundwater use without use measurement or formal fees and water rights is for irrigation districts to set surfacewater charges at rates slightly lower than the cost of pumping groundwater (Vaux 1986; Jenkins 1991). In this way, farmers will take surfacewater when it is available, allowing aquifers to recharge in wetter years. In dry years, when surfacewater is unavailable, farmers pump groundwater. Only for adjudicated aquifers, where the rights to use groundwater have been formally allocated by the courts, are water users required to submit water use reports, and local water masters appointed by the judge having jurisdiction.

Water contracts are common for water projects and districts, acting as wholesalers, to legally transmit water to more local wholesaling or retailing agencies. Ironically these contracts, which are not directly under state water rights administration, have the greatest water use reporting and accounting requirements. Accounting here is typically done by the water selling entity, such as the federal Central Valley Project. Measurements and accounting are typically at the wholesale delivery level.

Retail water accounting and measurement is generally far more accurate, particularly for urban water agencies in California. Most, but not all, major cities have metered water use for billing purposes. For agricultural water users, water use measurement is often less direct, with hours of withdrawals at a turn-out or irrigation canal water diversion point being translated into gross water use and billing. Sometimes farmers are merely billed per acre irrigated, rather than by gross water use. Private water retailers are regulated by the California Public Utility Commission. Public water retailers have generally lesser restrictions imposed by their enabling legislation and state law.

Water accounting in California is practised most precisely at the local level for total or gross water use, which is used for billing households, businesses and often farms for water use. Net water use is rarely estimated. One exception is the recent system of water charges for Irvine Ranch Water District, in Orange County in southern California. In this dry area, each customer's rate structure is individual in having a water allocation based on an indoor water use estimate (per capita) plus an estimated irrigation evapotranspiration based on individual property characteristics and local weather. Use below this allocation is priced much less than use above it. This unique rate structure requires estimation of net water use for each customer. Return flows (recoverable fraction) are reused in the district following treatment (Irvine Ranch Water District 2010).

At project and utility scales, water accounting is used for operational purposes. This is primarily to balance flows and allocate gross or total water use. Relatively little use is made of estimates of net water use, except locally by farmers for field scale water applications. At regional scales, there is an effort to account for both gross and net water use in the form of the California Department of Water Resources' water use portfolios. Each year since the late 1990s, the Department has estimated both gross water application and net water use for a variety of uses at a fairly local scale. These numbers are not used widely for water operations or rights enforcement, but are intended for planning and policy-making purposes (DWR 2010).

Overall, water accounting in California has become more advanced over the years, but further advancement can occur. Aside from the operation of water projects in real time and for water charges to customer, there is little operational use of water accounting. Most water accounting is done in terms of gross water use. Much less use is made of more difficult estimates of net water use, except in the regulation of water market transfers.

INACCURACIES IN FIELD MEASUREMENTS FOR WATER ACCOUNTING

Water accounting may balance mathematically, but it is likely to be far less exact physically. This was certainly true in Frontinus' ancient accounting of Rome's water supplies (Frontinus AD 97). Despite great improvements in water measurement and estimation, closure terms for mass balance estimations are rarely zero. For many metered urban water systems in developed countries, between 5 and 12 per cent of water remains unaccounted for, mostly between leaks and meter measurement errors (Johnson 1996; Alan Plummer Associates 2007).

Utility water deliveries and project water operations, which typically have resources and need for extensive flow metering devices and their calibration and maintenance, usually have better accounting for water deliveries. Regional water systems, with many more and varied hydrologic components, have more difficulty measuring the many parts of the hydrologic cycle at many locations throughout a region, over a wide range of conditions. During floods, for example, stream gauges are often outside of their calibrated range (because floods are rare or because of stream channel dynamics) and are often damaged or destroyed. In dry periods, the split of gross water use among evapotranspiration, return flows to streams and deep percolation to recharge groundwater are difficult to quantify, and might vary with near-term conditions of crop land cover, soil saturation and season. Yet these water accounting splits can be important for conjunctive use and water market management, and the economic revenues to different parties that come from such determinations.

Such unavoidable gaps and errors in water accounting impose a range of difficulties for water management, including the following:

1. Conjunctive use and water banking schemes have difficulty assessing who should own how much of banked water.
2. Water markets are hindered by controversies over how much water transactions affect water availability for other water users. In California, water transfers must pass a 'no harm' rule for other water rights holders (Hanak 2003, 2005).
3. Water use efficiency and water conservation efforts might not be effectively targeted (Hanak et al. 2010).
4. Water conservation efforts might actually increase net water use (Perry et al. 2009).
5. Water reuse efforts might increase regional water conflict by increasing consumptive use of discharges that had been used downstream.
6. Insufficient water might exist within the system for operational deliveries to be reliable. With tighter water flow estimation tolerances, more water can be made directly available for intended uses.
7. Water quantity effects on water quality might be insufficiently accounted for, such as when dilutions are expected to reduce contaminant concentrations below harmful thresholds.

Although imperfections in water accounting cause problems for water management, imperfect water accounting never precludes water management. However, it changes it.

ACCOUNTING FOR OTHER ENVIRONMENTAL FLUIDS

Water is not the only environmental fluid where accounting and measurement is of great importance. For example, quantities of oil and natural gas are more difficult to quantify within the environment. While measurement of oil and gas flows in pipelines are quite measureable, when oil is withdrawn from an underground reservoir that extends beneath several land or mineral rights owners, how is it determined which rights owner should be paid, or how much? This type of environmental fluid accounting is far more financially significant (per unit volume) than water, but it is far more difficult to estimate in the field. Yet obviously, such accounting occurs routinely, if not accurately, in oil and natural gas producing regions.

TECHNOLOGIES TO EXTEND FIELD MEASUREMENTS

Technological improvements such as new measurement technologies or improved regional water flow models might support water accounting benefits without imposing significant costs on water users.

New Measurement Technologies

Some new technologies promise to reduce the problems of water accounting at regional and utility scales. End-use metering used to require separate meters on each end use of a water user. Today, readings from smarter meters can be post-processed using signal processors to detect the combinations of end water user uses from a single meter in an individual household.[1] Remote sensing can also be used to estimate household irrigated area and perhaps ultimately evapotranspiration (IRWD 2010). Satellite imaging can be post-processed to estimate evapotranspiration from individual fields or even parts of fields (Courault, et al. 2005; Tsouni et al. 2008; System of National Accounts 2009; Thoreson et al. 2009).

Evapotranspiration (ET) is the greatest component of net water use in most inland cases. Having direct user-scale estimates of landscape evapotranspiration provides information needed for very disaggregated and more physically-based water use accounting and water rights enforcement. Remotely sensed data can be superior to water user reporting because: (1) it is likely to be less expensive to administer and enforce, (2) results will be more standardized and avoid variable forms of ET measurement by individual water users and (3) most individual water users have little capability to measure or estimate their ET anyway.

Regional Water Flow Models

Field data will always have imperfections and limitations. It will never be possible to have field measurements of all water accounting parameters at all spatial and temporal scales. Regional water models can be helpful here. Although use of computer models for water accounting has its own disadvantages, computer models of water flows for water accounting also have several distinct advantages. These include: (1) enforcement of consistency with known physical laws (mass balance) at localized and regional scales; (2) ability to estimate water accounting flows at many locations and across time steps and situations (such as the future) where field data would not be available, or overly costly; and (3) a standardized and transparent method of establishing flows needed for particular water accounting purposes.

Water accounting cannot rely on ubiquitous measurement that is not practicable. Estimates for locations and times without measurements, as well as error correction for measurements, can be provided in a physically consistent and standardized way through the use of models. While such models cannot be perfectly accurate, neither can field data. As coherent representatives of what we know about water flows in a region, computer models can become a standard and authoritative framework for water accounting for some circumstances.

HOPES, FEARS AND FANCIFUL NOTIONS IN WATER ACCOUNTING

More measurement of water use and more detailed water accounting raise both hopes and fears. For hopes, many expect tighter water use accounting and measurement will reduce and structure water conflicts and improve regional, local and user water use efficiency, with both economic and environmental benefits. Such improvements are potentially substantial, albeit at some cost for data gathering and analysis.

Fears also exist for improved water accounting. Water users who already feel adequately supplied often feel they can only lose from more complete quantification and accounting of water rights and use. Indeed, there is often a fear that quantification of a right is a first step to limiting and then diminishing a right. This has often been the case with Native American water rights in the US (Universities Council on Water Resources 1997). But it is also true of groundwater users in parts of California, who understand that growing demands and decreasing availability of surface-water could eventually impinge on their historical use of groundwater (Blomquist 1992). Opposition from existing users led to elimination of stronger groundwater use monitoring legislation in California in the fall of 2009.

Water accounting is also plagued by fanciful confused notions of water accounting systems that have become popular and even award-winning. These include such notions as virtual, green and blue water, as well as accounting based on water footprints, full cost and life-cycle. These notions are all well-intended and often have a core of innovative or novel thinking. However, on the whole they distract from more physically, economically and environmentally substantive water management and accounting. The physics of water cares little for such colourful notional distinctions. Basing water accounting on physically and operationally confused notions can only undermine the social, legal, economic and environmental purposes of water accounting.

Among these confusions, fears and opportunities are the politics of strengthening water use reporting and water accounting.

COMBAT ACCOUNTING

Water management is driven by human interests in water. These interests are economic, social, political and environmental. Water accounting is a technical and legal means towards these often conflicting ends. The underlying conflicts will often lead to efforts to alter or undermine water accounting systems for the benefit of one or more interests. This leads to what might be called 'combat accounting' where particular interests seek to alter or manipulate a water accounting system for a particular interest. This can be done by assailing field measurements or calculated estimates of water availability or use. In water market transfers, for example, sellers have an interest in inflating their net water use, which is available for sale, while downstream users have an interest in deflating the water seller's net water use to make more water available downstream. Given the imperfectable nature of water flow estimation, these manipulations are technically easy. However, successful combat water accounting ultimately undermines overall water rights, contacts, agreement and accounting systems. All parties have an interest in a strong, reliable accounting system, but can also have particular interests in evading or bending these systems. Changes or improvements to a water accounting framework also involves combat accounting, as interests seek an accounting system that best serves them. In California, this has led to the long exemptions of groundwater and grandfathered surfacewater uses from the water rights permit system.

CONCLUSIONS

Water accounting in California has slowly increased and improved with time, but remains sparse and rudimentary. As California's economy and population continue to grow and its water demands continue to grow and diversify, the existing system of water accounting will become less functional and lead to increasing conflict. More complete and formal water accounting and measurement will become still more desirable and important. Nevertheless, political, institutional and practical impediments exist to improving water accounting.

Ideally, improvements to California's water accounting system should:

1. base the accounting system on physical reality, using net water use and including groundwater and stream–aquifer interactions;
2. improve the relevance of the accounting and water rights system to contemporary and future water management operations and policy issues;
3. make greater use of remote sensing estimates of net water use and authoritative hydrologic modelling where field data are sparse and inaccurate;
4. seek to forestall most combat accounting; and
5. avoid the distractions of fanciful water accounting notions.

Improved technologies for measuring consumptive water use remotely and computer modelling of regional hydrologic flows are likely to provide means for a more standardized and complete accounting of water use and flows. In this case, more physically-based calibrated model representations of uses and flows might become authoritative substitutes for more expensive and often less reliable field measurements, which also require land owner cooperation.

NOTE

1. See, for example, Aquacraft Water Engineering and Management, at www.aquacraft.com; accessed 15 October 2011.

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15. Accounting for water rights in the western United States

Mark Squillace

INTRODUCTION

The western United States is renowned for its system of allocating water by prior appropriation (Beck and Kelley 2009).[1] Under this system, those parties who first acquired the right to use water receive their entire allocation before later appropriators receive any (Sax et al. 2006; Getches 2009).[2] When a water source is fully depleted, water deliveries stop. Western US water rights are, however, limited to beneficial use, which means that water users must not waste water and must adopt reasonably efficient practices, both for diverting water from the watercourse and for applying it to the approved use.

Two implicit assumptions about water management in the western US are that (1) the amount of water diverted for and consumed by individual uses can be accurately measured and (2) water resources are not diverted in excess of legal rights. Somewhat surprisingly, the validity of these assumptions is rarely questioned. A related problem that is rarely raised unless a water rights owner proposes to sell the rights is how much water is beneficially consumed by the historic water user.

As water resources in the western US become increasingly scarce, it is fair to ask that water users and the agency officials who regulate them provide basic information about the accuracy of water diversions and the scope of water use. This chapter offers insights into how accurate information about water diversions and use might be gathered and used to achieve better water resource management, and how regulatory agencies might better promote more accurate accounting through regulatory standards and incentives.

MEASURING WATER DIVERSIONS

Parties involved in the administration of water rights (including agency personnel, water districts and ditch companies,[3] water lawyers and courts, and ultimately end water users) all assume that the system provides for the accurate measurement of water diversions. Yet measuring water diversions in the field usually depends on rather simple, even crude, devices, which may not justify the confidence typically placed upon them. Of particular concern are diversions for agricultural uses, which consume as much as 90 per cent of the water supply in the western US (Solley et al. 1998).[4] Given the vast amount of water consumed by agriculture and the high demand associated with that water for municipal and other uses, even relatively small errors in measurement can significantly impact the availability of water supplies, especially if the errors are primarily in one direction and tend to favour higher diversions than would otherwise be allowed.[5] To understand the potential scope of the problem it is important to consider how water diversions are measured, particularly for agricultural diversions.

Devices for Measuring Water Diversions

Agricultural water rights and some smaller non-agricultural water rights, like domestic water rights, have historically been measured in terms of the rate of diversion. For surfacewaters, the rate of diversion is typically expressed in terms of cubic feet per second or cfs. For groundwater, diversions are usually measured in gallons per minute or gpm. The US Bureau of Reclamation (USBR) has developed a *Water Measurement Manual* over the course of many years that provides substantial technical guidance to parties interested in measuring water diversions (USBR 2001). The remainder of this section is derived from that manual, unless otherwise stated.

The most common device for measuring water rights of individual agricultural users is the flume. Flumes are open-channel devices that are shaped to force flow to accelerate. This acceleration is accomplished by 'converging the sidewalls, raising the bottom, or a combination of both' (USBR 2001, p. 8–1). Flumes vary in size and shape depending on the purpose for which they are used. For example, the Palmer-Bowles flume is used to measure water and wastewater in open channels or pipelines that are not under pressure,[6] while the H-flume measures flows from agricultural field runoff.[7] The Parshall flume[8] is one of the most widely used flumes in the world for measuring surface flow (Abt et al. 1995). The Parshall flume is particularly suitable for measuring flow in irrigation ditches and canals, because unlike other flumes, it requires very small head loss, readily passes sediment that might otherwise lead to inaccurate measurements and does not require a large upstream stilling section (Cusick 1957). If a Parshall flume is properly constructed, installed and maintained, its accuracy should be within 3 to 5 per cent. Flumes that are poorly constructed however, or that are installed improperly, can be quite inaccurate. Construction errors are especially common for custom-built flumes. Parshall flumes should be installed on a stable, solid foundation and in tranquil flow conditions with mild slopes and straight channels that are free of curves, projections and waves. The flume's foundation should also be sealed to prevent leakage around and beneath the flume, which could cause uneven settlement or heaving, especially in the winter. Once a flume is installed properly, it must be monitored to ensure that it continues to function accurately.

Basic maintenance of flumes, including removal of debris and re-levelling the device, should be performed regularly as needed, and at least once per year. After a flume has been installed, the foundation may shift, thereby significantly compromising the accuracy of the flume (Abt et al. 1995). Frost heaving often occurs during the first winter after the flume is installed, especially in colder climates. As water expands, the soil expands and then contracts with the winter thaw, causing the ground to shift the flume. Such a shift will rarely affect large Parshall flumes diverting water from a river; however, the smaller the flume, the more likely that even a slight ground shift will affect the reading. Although the most significant frost heaving is likely to occur the first winter after the flume is set, it can occur years or even decades later. Therefore, annual spring inspections are necessary to check accuracy and re-level gauges, especially at higher elevations where extreme weather conditions are most likely to occur.[9] In addition, rocks, trash and sediment can become trapped in the flume floor and lead to inaccurate measurement. Other common sources of error are misreading measurement devices and allowing the flume to become submerged.

Accurate Parshall flume diversions are important because these flumes are used to divert thousands of acre-feet from streams and rivers into ditches and canals. Some diverters employ advanced technology to ensure greater accuracy. In particular, transit-time acoustic (ultrasonic) flowmeters, which measure the transit time of signals sent across the waterway, are highly accurate.[10] Another way to improve accuracy is to install recorders at head gates. These recorders correspond with a central database that transmits real-time data for all water diversions within a water basin, district or ditch company.

Despite their popularity and widespread use, the Bureau of Reclamation has suggested that Parshall flumes are inferior to long-throated flumes. The *Water Measurement Manual* describes '[a] simple type of long-throated flume [as consisting] of a flat raised sill or crest across a trapezoidal channel with an approach ramp transition from the approach channel invert' (USBR 2001, p. 8–13). In comparison to Parshall flumes, 'long-throated flumes are more accurate, cost less, have better technical performance, and can be computer designed and calibrated' (ibid.). Ironically, states rarely require that water users employ the more accurate measuring devices. Indeed, some state laws specifically require the use of the less accurate Parshall flumes.

The amount of water that passes through a flume is typically measured with a staff gauge that is attached to the sidewall of the flume. The staff gauge is a simple and inexpensive device that looks like a ruler, with numbers and hash marks that are set to correspond with flow rates. More accurate measurements can be obtained with a stilling well. A stilling well is a simple well installed adjacent to a flume or stream connected by an orifice. The well level gives a more accurate reading of the head in the flume or stream since it avoids the turbulence that can occur in the flume. As the *Water Measurement Manual* explains, with a stilling well 'the average water surface outside the well is translocated into the well, and the waves and fluctuations are dampened' (USBR 2001, p. 6–8). Stilling wells offer another significant advantage in that they can incorporate an electronic data logger that allows for real time monitoring of all the water that passes through the flume. By contrast, staff gauges cannot practically be read with the frequency necessary to accurately reflect total flow through the flume. Nonetheless, staff gauges do provide an important back-up mechanism for checking the accuracy of the information obtained from stilling wells. While stilling wells and electronic data loggers may be impractical for some smaller diversions, they should arguably be required for larger diversions where greater accuracy is especially important.

Weirs are one of the oldest structures used to measure the rate of water flow in open channels. Weirs are relatively simple, low-cost devices that are often used in streams, small rivers and ditches. Weirs are constructed perpendicular to an open channel, with limited water flowing atop of the structure. Similar to flumes, weirs are susceptible to water oscillations and sudden, increased flows. Therefore, they must be installed with a deep, still pool upstream to function accurately (Cusick 1957). Properly installed weirs can operate with at least 95 per cent accuracy.

The biggest source of error for both flumes and weirs is human, especially errors involving stage measurement, which is essentially the height of the water over an established baseline. Stage measurement can be a major source of error if measurements are not taken constantly since water levels can fluctuate substantially over a short period of time. In many systems, measurements are taken daily, or only when there is a change in water supply or delivery. Unless measurements are taken with something akin to an automatic data logger (described below), problems introduced by rising or falling head or rising backwater will be ignored, producing misleading data. Other significant errors may arise from build-ups of debris and sediment and regular inspection and debris removal are necessary to avoid significant measurement errors.

Another common source of error is irrigation system deterioration, which can exist for years before becoming apparent. Regularly inspecting an irrigation system for signs of deterioration in the early stages will minimize error. A series of small problems can compound into a large, unknown and unaccountable error. Fixing small problems will extend the life of measuring devices, ensure accuracy and prevent the replacement of the entire device.

Better accounting practices will lead to more accurate water diversions. Over the past quarter-century, technological advances, including satellites and the Internet, have made improved water accounting possible. For example, data loggers are increasingly used at significant diversion points. Data loggers essentially employ a monitoring gauge connected to a modem. The modem automatically transmits the gauge readings to a central database, allowing for 24-hour monitoring of water levels. Posting this data on a website would afford real-time information to all interested water users. Without data loggers, water commissioners must convert water stages to flow rates using a paper chart and conversion equations. This time-consuming process introduces the possibility of human error into every calculation. In contrast, data loggers are pre-programmed with the correct formulae, thereby increasing efficiency and minimizing human computational errors.

As more complex terms and conditions are attached to water rights, improved accounting methods become increasingly imperative. In recognition of this reality, the Colorado Division of Water Resources (CODWR) began converting recording stations to data loggers in the 1980s (Ley et al. 2010). The conversion has accelerated over the past seven years, and today CODWR has 518 data loggers located throughout the state.[11] Although engineering studies have periodically assessed the accuracy of flumes and other water measuring devices both in the lab and in the field,[12] little work has been done to assess the costs and benefits of more accurate measuring devices and more careful supervision of those responsible for ensuring the accuracy of these devices in the delivery of water. Among the potential benefits of better measurement is the prospect of keeping more water in the stream, thereby protecting instream values.

Accounting for Water Resource Diversions in the Field

Good water accounting practices require trained personnel, and states generally employ trained water commissioners, or more colloquially, ditch riders,[13] to ensure that water users receive no more water than they are entitled to receive based upon the amount and priority date of their water rights (Wolfe 2005). One of the chief tasks of the ditch rider is to open and shut headgates as necessary to protect these priorities. For those rights that are in priority, the ditch rider must also ensure that the amount of water diverted does not exceed the diverter's water right (ibid.). Water commissioners and their deputies are also responsible for reading flumes at the point of diversion and monitoring recorders to ensure their accuracy.[14] Hydrographers support the water commissioners by monitoring flumes and correcting inaccuracies.

The State of Colorado offers an excellent example of how states organize and operate water management systems. Colorado law divides the state into seven water divisions corresponding with seven major drainage basins (Colo. Rev. Stat. § 37-92-201 2010). The Colorado State Engineer oversees seven water engineers, one per division. The water divisions are divided into 78 water districts, with at least one water commissioner per district. Hydrographers provide technical support to the commissioners.

Since rivers and streams fluctuate significantly in response to precipitation, reservoir releases and snow melt, commissioners must learn to anticipate these events and plan their work accordingly. Unless remote monitoring is available, commissioners must usually check every ditch at least weekly during the irrigation season both to monitor flows and the accuracy of the diversion device. If a problem with a device is suspected, a hydrographer will be called in to reset the device (Wolfe 2005).

While ensuring accurate measurements is important, the system is fraught with other potential errors. Most problematically, because state officials do not generally require real-time data loggers, most diversions necessarily rely on the honour system, with water users policing themselves and their neighbours to ensure that they use no more water than is allocated to each appropriator (ibid.). This system probably avoids the most egregious violations, especially where another water user may be adversely impacted, but incentives favour overuse because overuse benefits the water rights owner and may not be discovered until substantial excess water has passed through that user's headgate.

More accurate measurements are likely for water users who receive their water from a 'mutual ditch company' or water district. These organizations distribute vast quantities of water through common ditches and canals that carry water to smaller lateral ditches, which deliver water to individual farms.[15] Because the mutual ditch companies and the water districts hold legal title to all of the water rights that pass through their main canals,[16] the accuracy of any measurements is only of concern at the initial point of diversion, since that is the point at which the priority rights are satisfied for all members of the company or district. Moreover, because large volumes of water typically pass through these main canals, water commissioners have powerful incentives to employ the most accurate measuring devices, including electronic data loggers.

The Special Circumstances of Storage Water Rights

Water rights that depend on storage facilities raise unique issues for water accounting. Because of the costs associated with building and maintaining storage facilities, storage water rights most often involve large water rights held by municipal water suppliers, irrigation districts, mutual ditch companies and industrial water users. In terms of water accounting, water storage rights hold several potential advantages. Perhaps most importantly, stored water rights are typically measured by volume rather than flow (Funk 2006). Volumetric rights are typically expressed in acre-feet. For water rights based on the rate of diversion, the volume of water allocated to an individual user can fluctuate dramatically over the course of years since it depends on the duration of the diversion and whether the diversion fluctuates below the maximum rate. By contrast, volumetric rights are typically accessed in the spring and the volume taken in any given year can be fairly easily and accurately ascertained by measuring inflows, outflows and the change in elevation of the reservoir (ibid.).

ACCOUNTING FOR CONSUMPTIVE USE

Defining Water Rights by Consumptive Use

Whether a water right is expressed in terms of cubic feet per second or acre-feet, once the water has been used for its approved purpose it must generally be released and made available for other water users.[17] This follows from a general principle of western US water law that requires beneficial use without waste.[18] Given that the amount of water diverted will rarely, if ever, be fully consumed, quantifying the consumptive amount associated with any water right and ensuring that water users stay within their consumptive use limits would appear to be at least as important as quantifying the amount of water that is diverted. This is because the consumptive amount is, in many respects, the true measure of the water right. Unfortunately, while western US water law precisely defines diversion rights, it does a stunningly poor job of defining consumptive use rights. The consequence of this failure is significant, because it seriously compromises the marketability of water rights, as described in more detail below. But the failure to account for consumptive use is a serious problem even beyond the marketability of water rights. In particular, the failure to define a water right in terms of its consumptive use means that the consumptive amount may fluctuate over time, even fluctuate substantially, to the detriment of other water users. Fluctuations may occur, for example, simply because a farmer decides to grow a crop that happens to consume more water or because the farmer decides to recapture and reuse the water after it has already been applied to a field.[19] Longer growing seasons that may attend a warming climate could also increase consumption (Bates et al. 2008).

The possibility that water consumption may fluctuate substantially due to lawful changes in the use of a water right causes great uncertainty. Uncertainty is anathema to an efficient system of water rights since investors are less likely to support projects for which the availability of water is in doubt. Moreover, because water transfers in western US states are typically based upon historic consumptive amounts, water rights owners have a powerful economic incentive to maximize their consumption, thereby enhancing the amount of water potentially available for transfer. The consequence of this incentive is to constantly reduce the amount of water available for new uses.

Water Transfers and Consumptive Use

The early years of prior appropriation law were marked by a fair degree of hostility, at least in some quarters, to allowing water transfers at all (Gould 1989).[20] This was largely due to concerns over speculation.[21] Appropriators who were able to secure more water than they really needed might reap a bounty in the future by selling their excess supply. A strict prohibition on transferring water would thus discourage excessive appropriations by taking away any prospect that water could be sold to another user. Over time, as most of the valuable water rights were allocated, the possibility of transferring water from existing users was one of the few ways that new users could obtain adequate supplies.[22] As a result, most states now allow and even encourage water transfers,[23] subject to the requirement that the transfer of water does not injure existing users. But injury can occur in a host of ways – from changing the point of diversion to interfering with the location or timing of return flows.[24] As a general proposition however, no one should suffer any substantial injury so long as the transferee of the water limits use to the amount of water historically consumed by the transferor.

Unfortunately, courts that have considered challenges to water transfers have often failed to focus on what might otherwise be a rather simple rule of allowing transfers of the full consumptive use amount (see, for example, *Basin Electric Coop*. v. *Wyoming Bd. of Control*, Wyo. 1978). Nonetheless, consumptive use is usually an important factor in determining whether an injury has occurred, and accounting for it up-front when water rights are allocated could go a long way to streamlining the transfer process.

While it might seem surprising that parties would fight over what on the surface would appear to be minor disagreements regarding the amount of water consumed by crops, these fights often serve as a proxy for the larger issue of protecting the economies and cultural values of rural farmlands.[25] Still, the potential advantages of defining water rights in terms of consumptive use and then allowing presumptive transfers of those consumptive amounts are potentially enormous.

Resource economists have touted the value of water markets for many years (see, for example, Howe et al. 1986), but the goal of establishing transparent and free water markets has proved far more elusive than for most other resources.[26] Nonetheless, the prospect that water rights could be defined in terms of consumptive use and that transfers of consumptive use amounts could be carried out without substantial bureaucratic costs is tantalizing because of the promise it holds for overcoming decades of obstacles to running efficient water markets. However, that promise is unlikely to be realized unless states are able and willing to define water rights in terms of consumptive use and to presumptively allow transfers of those consumptive amounts even where de minimis injuries might occur, just as they do when water diversions are not accurately measured.

REGULATORY MECHANISMS FOR IMPROVING WATER ACCOUNTING

Standards for Promoting Greater Accuracy for Diversions

Western US states currently have the authority to demand greater accuracy in measuring the amount of water diverted. Rarely, however, do they exercise this authority. For an individual water right, the amount of water that is likely to be lost as a result of inaccurate measurements is likely to be small. But cumulatively, these errors could represent a substantial amount of water. And if all or most of those errors favour the water rights holder, then other water needs, including in stream needs, are potentially being deprived of substantial quantities of water.

Requiring the most accurate water measuring devices will not make economic sense in all cases. But states can and should insist that some assessment be made of the feasibility of installing more accurate measuring devices and more transparent systems for collecting and reporting diversion data.

Defining Water Rights in Terms of Consumptive Use

As described in the discussion of water diversions, accounting for water is an inexact science. Even when perfectly designed and installed, flumes and weirs are not likely to achieve 100 per cent accuracy, and additional accounting errors inevitably result from the vagaries of the field conditions where such devices are used. Despite these limitations, flumes and weirs are generally accepted as appropriate devices for measuring water diversions.

Like accounting for diversions, accounting for consumption is an inexact science. But just as the priority system tolerates the minor inaccuracies that attend the use of flumes and weirs, so too can the system tolerate the minor inaccuracies associated with quantifying consumptive use. Defining water rights in terms of both diversion amount and consumptive use will take time, but it should not prove especially challenging. It could be carried out by the water management agency and informed by the work of the American agricultural colleges and the US Department of Agriculture, which have developed reasonably good data on consumption rates by crop and soil type.

Defining water rights in terms of both the diversion amount and the consumptive use offers the potential for achieving the holy grail of freely marketable water rights (see, for example, Committee on Western Water Management and National Research Council, 1992; Kenney 2001). But states will have to make clear, probably through legislation, that the consumptive amount of any water rights can be freely transferred, at least within the same water basin, without regard to any de minimis injuries that might result. Consumptive use of water is, of course, important even today when a party seeks to transfer water rights. Typically, states look to consumptive use as a starting point for determining whether downstream users are injured.[27] But the current law in essentially all prior appropriation states promotes a battle of experts that plays out in state courts as a fight over the most minor injuries or changes to the existing water resources regime. The costs, in terms of legal and expert witness fees, and the uncertainty, in terms of the amount of time the process can take and the amount of water that the court will ultimately approve for transfer, can discourage even the most optimistic proponents of water markets.

Water law reforms are plainly needed to deny a cause of action for minor injuries that occur when consumptive rights are transferred to other users. Indeed, since such injuries are essentially limited to possible changes in the timing of return flows and possible errors in measuring consumption rates, they are no more serious than errors that arise due to inaccurate diversion measurements. Moreover, in many cases potential injuries are likely to be less significant than those the system currently tolerates, like allowing farmers to grow more water-intensive crops (often in anticipation of some future transfer proposal), or allowing a farmer to recapture and reuse water so long as that water is applied to the land for which the right was originally appropriated and for the same use (*Binning* v. *Miller*, Wyo. 1940).

Tolerating minor injuries that could result from inaccuracies in accounting for consumptive rights of what are acknowledged in all western US states to be the public's water resources would allow a robust water market to evolve, thereby promoting the most efficient use of the region's limited water resources. And a system that required quantification of consumptive rights in advance of any proposal to transfer water would help to regularize the idea that consumptive rights should form the basis for any future efforts to market water.

Accounting for Seasonal Use

While municipal and industrial water uses are generally needed throughout the year, agricultural uses are seasonal. However, weather conditions vary from year to year, and with those variations the length of the irrigation season may change. Historically, and over time, these variations have tended to balance out so that an average irrigation season can be identified. Perhaps because natural weather patterns have proved reliable within a historic range, it has not seemed necessary in most situations to identify with specificity the exact length of the irrigation season in the water right itself. Enter climate change. As average temperatures rise, the growing season gets longer. Junior users, especially non-irrigation users who could historically rely on an identifiable average irrigation season, now face the prospect of an average season that may be longer by a week or two on either end. [28] Irrigating crops for an extra two to four weeks inevitably leads to consuming more water than was historically consumed. The impact on the total water supply if many agricultural users take advantage of this longer season could be profound.

Accounting for seasonal use, by explicitly and narrowly identifying the time period over which the water right is available, should become a priority in all prior appropriation states. And in order to avoid unfairly enlarging agricultural water rights, the length of the irrigation season should be limited to the average time period over which water rights were used before observable changes in the climate.[29]

THE POTENTIAL ADVANTAGES OF IMPROVED WATER ACCOUNTING

All water rights within a single basin are intertwined with one another. One party's water use necessarily impacts the ability of every other party to use water from that same stream. If a senior party is using more water than was historically used (either because of inaccurate measuring devices, extended growing seasons or other excessive consumption beyond historical practices), that excessive use can affect every other user on that stream.

Better accounting of water resources withdrawals and consumption, along with clearer restrictions on the seasonal limits of water rights, will help create certainty about the scope of individual water rights. This is the hallmark of any well-functioning property rights system. No doubt a great deal of uncertainty regarding various aspects of any water rights will remain. Diversion devices will remain marginally inaccurate, even as more sophisticated devices are employed and methods for monitoring them improve. Consumptive rates, which depend upon soil types, precipitation rates and crops grown, can be estimated, but not with perfect accuracy. It may also be difficult to determine the amount of water saved as a result of improved accounting methods. However, given that the diversion devices commonly in use for agricultural diversions are only accurate to within 5 to 10 per cent, even when properly installed and maintained, and given that errors that favour the water user are less likely to be corrected in a timely fashion, some savings from better accounting methods seems inevitable. And the potential for savings is quite remarkable.

The United States Geological Survey (USGS) estimates the amount of freshwater use by sector and state every five years (Kenny et al. 2009). In its most recent reports, the USGS has focused exclusively on water withdrawals as opposed to water consumption, but these figures nonetheless offer a useful window onto the potential savings from better accounting methods. Consider, for example, the figures from 2005 for the states of California and Colorado (ibid.). The USGS estimates that agricultural users in California withdrew 24.4 billions of gallons of water per day. In Colorado, they withdrew 12.3 billions of gallons of water per day. Most likely, the measurements for some of these withdrawals were made using stilling wells and electronic gauges and were thus more accurate than others, and some errors went both ways and thus balanced each other out. Still, if the assumption is correct that the error rate for well-installed and maintained mechanical diversion devices is about 5 to 10 per cent and that the errors tend to favour water diverters, then it seems fair to estimate that more accurate measuring practices might save at least 1 per cent of the total water withdrawn. Of course, had this water been withdrawn and applied to the land as much as half of it might have returned to the stream as return flows, so only about one-half of this 1 per cent might actually be saved. But one-half of 1 per cent of all the agricultural water withdrawn in the western US is a lot of water!

Consider again the figures from California and Colorado. One-half of 1 per cent of California's 24.4 billion gallons per day of agricultural water is 122 million gallons per day. Assuming an average per capita consumption of 125 gallons per day,[30] this is enough water to satisfy the annual domestic needs of nearly 1 million people. For Colorado, the figures are about half what they are in California: a saving of approximately 61.5 million gallons per day, and enough water to meet the annual domestic needs of almost 500 000 people. In terms of volume, the amount of water saved each year would be more than 137 000 acre-feet for California and more than 69 000 acre-feet for Colorado. The value of this saved water is harder to calculate since the price of water varies greatly depending on its location and the availability of an adequate system for conveying the water to the place where it is needed. But water rights along the Front Range of Colorado, where elaborate conveyancing systems already exist, are well into the thousands of dollars per acre-foot.[31] Of course, the possibility exists that the savings (and corresponding benefits) would be far greater than one-half of 1 per cent. But even modest efforts to introduce greater accuracy into the water accounting system would seem, at first blush, to be well worth the effort.

Unfortunately, even the substantial water resource savings that might result from improved measurement accuracy may be chimerical, since the water that is saved will not likely become available to satisfy currently unmet water needs, including environmental and urban water supply needs. This is because under the prior appropriation system any water saved by better accounting will likely inure to the benefit of junior water users, especially on those streams that are already experiencing shortages. Thus, improved accuracy might simply mean more water for junior appropriators over a longer period of time. While it might be possible to find some means to share the water savings between junior users and environmental or urban users, changes to current state law will likely be necessary to accomplish that result.

REGULATORY MECHANISMS FOR IMPROVING WATER ACCOUNTING

Assuming that western US states would like to improve their water accounting systems, two questions remain: (1) do states have sufficient legal authority to require water users to employ more accurate systems to account for their diversions and consumption; and (2) if states have such authority, how should they go about the process of improving their accounting systems?

There is a surprising dearth of law regarding the authority of states to require water users to use any particular type of measurement system. However, most states establish general requirements for constructing appropriate devices for measuring the water that passes through a ditch for irrigation or other purposes. One of the more explicit is that of the State of Colorado, which requires the water user to 'construct suitable and proper measuring flumes or weirs, equipped with self-registering devices if required by the State Engineer, for the proper and accurate determination of the amount and flow of water turned into, carried through, and diverted out of [any stream]' (Colo. Rev. Stat. § 37-84-113 2010). But even where state laws are less clear about the authority to require measuring devices that meet certain standards for accuracy and transparency, such power must be presumed from the fact that western US states are required to manage water resources as a trust resource for the benefit of the people.[32] Thus, any state that chooses to demand a more accurate and transparent system for measuring water diversions is surely acting within the scope of its authority.

The more challenging question is how states can achieve a more accountable system that makes sense in terms of the costs that will have to be borne and the benefits that will be realized. Certainly, states could simply mandate that all water diversions, or perhaps all diversions over some modest threshold, would have to use best available technologies for measuring their diversions by some set deadline. Such technologies might be defined as those that can be achieved at a reasonable cost, given the benefits that are likely to be achieved. This would avoid criticism that states are mandating a one-size-fits-all approach to addressing very different situations. But while mandating wholesale and potentially costly improvements for measuring the thousands of water diversions across an entire state might make sense, states should consider a more methodical, staged approach that targets streams that are most stressed and regions where better measuring devices are likely to yield the most significant improvements in accuracy. States should also use these initial efforts to test the benefits of different flume technologies and electronic logging devices. Such an approach will allow the states to better understand whether particular technologies and practices afford benefits in terms of improved accuracy and more efficient monitoring of water diversions sufficient to justify more widespread application.

Perhaps the more pressing need is for states to demand that water rights be defined in terms of consumptive use and that seasonal water rights be specifically tagged with exact dates that reflect historical seasonal averages. Once again, any such reforms would likely have to be carried out in phases, with water-stressed areas given the highest priority. But the benefits here, especially in terms of how such reforms might open water markets, are potentially enormous.

CONCLUSION

In the western US, water accounting is most often thought of in terms of more accurately measuring water diversions. Certainly, better water diversion accounting makes good sense and states should recognize the significant amounts of water that are potentially misallocated by the acceptance of inadequate measurement technologies. While better accounting of diversions would not necessarily generate water resources that could protect environmental values or satisfy the growing demands of urban areas, it would surely promote more efficient use of scarce water resources.

Accounting for consumptive and seasonal use raises an entirely different set of issues that typically arise only where a water right owner proposes to sell the right. But defining water rights in terms of their consumptive and seasonal use could promote thriving water markets and possibly signal a new and progressive era of water resources management in the western US.

NOTES

1. Fifteen of the 18 western US states view prior appropriation as the only method for acquiring new surfacewater rights (Beck and Kelley 2009).
2. By contrast, water allocation systems in most other states and in many other countries operate on sharing principles that require all users on a system to share proportionately when water supplies are not adequate to satisfy demand (see generally Sax et al. 2006; Getches 2009). Under the Model Water Code, a state agency may issue a permit to a person entitling that person to hold and exercise a water right involving the withdrawal of a specific quantity of water at a specific time and place for a specific reasonable use. However, the state agency may restrict any term or condition of any permit for the duration of a water emergency, 'a shortfall in supply that endangers the public health, safety, or welfare' (Dellapenna 1997).
3. In the US, most states provide for the establishment of quasi-public agencies, often called irrigation districts or conservancy districts, that hold water rights in conjunction with a large, publicly financed and subsidized water storage and distribution system. A ditch company or mutual ditch company is a private entity whereby water users hold shares in the company that correspond to proportionate water rights. Like water districts, ditch companies often own storage and distribution facilities and assess their

shareholders for the cost of building and maintaining these facilities (see Sax et al. 2006, pp. 682–5).

4. Total freshwater consumption in the US for 1995 (the last year for which the US Geological Survey compiled figures for water consumption as opposed to water withdrawals) was approximately 100 billion gallons per day, 6 per cent more than during 1990. Of that amount, 81.3 billion gallons went towards irrigation. For states west of the Mississippi River, irrigation generally accounted for over 90 per cent of freshwater consumption. California consumed about 25.5 billion gallons per day of freshwater, 23.5 billion gallons of which was for irrigation. Arizona consumed 3.83 billion gallons of freshwater per day, 3.18 billion of which was for irrigation. Idaho consumed 4.34 billion gallons of water per day, 4.31 billion gallons of which was for irrigation (Solley et al. 1998).
5. Errors will likely favour the water user since all water users have a strong incentive to insist that they receive their full allocation, but very little incentive to correct errors that might lead to an over-allocation of water.
6. Palmer-Bowles flumes are 'frequently made as inserts with circular bottoms that conveniently fit into U-shaped channels or partially full pipes. These flumes make a transition from a circular bottom section to a raised trapezoidal throat and transition back to a circular bottom section' (USBR 2001, p. 8–4).
7. The *Water Measurement Manual* describes H-flumes as 'made of simple trapezoidal flat surfaces. These surfaces are placed to form vertical converging sidewalls. The downstream edges of the trapezoidal sides slope upward toward the upstream approach, forming a notch that gets progressively wider with distance from the bottom. These flumes should not be submerged more than 30 per cent' (USBR 2001, p. 8–4).
8. Bothered by problems with stream flow measurements, Ralph L. Parshall developed a flume that, when placed in a channel, measures the flow of the water as it uniquely relates to water depth. Parshall developed the flume in 1921 while on the faculty at Colorado State University (Smith 2004).
9. Interview by Chris Reagan with Dave Nettles, Division Engineer, Colorado Division of Water Resources, Division 1, in Greeley, CO (21 July, 2010).
10. These flowmeters are based on the principle that 'the transit time of an acoustic signal along a known path is altered by the fluid velocity. A high-frequency acoustic signal sent upstream travels slower than a signal sent downstream. By accurately measuring the transit times of signals sent in both directions along a diagonal path, the average path velocity can be calculated' (USBR 2001, p. 11)
11. The United States Geological Survey, along with other federal, state and local agencies, operate another 384 gauging stations in Colorado, for a total of 902 satellite-monitored gauging stations in the state (Ley et al. 2010 p. 7).
12. See, for example, Abt and Ruth (1997) (field study of 66 Parshall flumes to assess physical integrity, settlement and submergence).
13. This label derives from the not-so-distant past when individuals would ride their horses along the ditch to open and shut headgates, clean debris out of the ditches and deal with problems such as leaks, floods, irate neighbours, children building dams and unhappy water users (The Ditch Project).
14. 'Water commissioners have one of the most important duties of any employee within the Division of Water Resources, which is to properly distribute water according to the priority system. They must be available 24 hours a day, seven days a week, to respond to requests for water. Complete and accurate records must be kept of where they have been, what they have done, and what they have observed' (Wolfe 2005, p. 13).
15. The typical ditch company is a mutual ditch company, where farmers own shares in the company based on the farmers' pro-rata share of water rights or the number of acres the farmer irrigates. The ditch companies levy assessments against stockholders to raise funds to maintain and operate the irrigation system (Grant and Weber 2010).
16. However, '[w]hile the "naked title" may stand in the name of [the mutual ditch

company], the ditch, reservoir and water rights are actually owned by the farmers who are served thereby' (*Jacobucci* v. *Dist. Court*, Colo. 1975, p. 674).

17. See, for example, *City of Thornton* v. *Bijou Irrigation*. Co., Colo. 1996. This restriction does not apply, however, to water that is imported from another basin. Water rights can sometimes be reused, however, such as when a user can establish, through appropriation, a right in the return flow (see, for example, *Water Supply and Storage Co*. v. *Curtis*, Colo. 1987).
18. 'Beneficial use' is the 'basis, the measure and the limit' of any appropriative water right. The concept of beneficial use encompasses both the type of use and the amount of water available for that use. It is generally designed to ensure against wasteful uses of wasteful practices (Sax et al. 2006, p. 152–9 n. 2).
19. In most western US states, an appropriator may reuse seepage and wastewater so long as it is recaptured and reused on the land and for the purpose for which it was originally appropriated (see, for example, *In re Uintah Basin*, Utah (2006); *Fuss* v. *Franks*, Wyo. 1980).
20. Many states enacted statutes to impede transfers of water rights in order to protect junior appropriators, discourage speculation, or promote social policies by, for example, prohibiting transfers of agricultural water to energy use in order to 'preserve the agricultural ambience of the state' (Gould 1989).
21. In Elwood Mead's classic book on water rights, Mead argues that:

    > If [the right to transfer water] is [sustained], water rights . . . will become personal property. The water of public streams will become a form of merchandise, and limitations to beneficial use a mere legal fiction. It will render futile and useless the requirement of the State statute that the lands to which the appropriation is attached must be described in certificates, because the right can be separated from this land without any legal formality as soon as the certificate is recorded. If water is to be so bartered and sold, then the public should not give streams away, but should auction them off to the highest bidder (1903, p. 264).

22. The other principal means for obtaining new water supplies was the construction of large projects that could store spring runoff from the western US mountains, and in some cases, divert water over the Continental Divide. Most of these projects would not likely have been accomplished without substantial funding from the federal government.
23. California allows water users who reduce their water use through conservation or eliminating waste to transfer the excess water or water rights (Cal. Water Code § 1011 2009), and further allows users to transfer excess water created by using reclaimed or polluted water (Cal. Water Code § 1010 2009).
24. Changes in use can also produce indirect adverse effects such as a decline in the local economy, erosion of the tax base, general social disruption from transferring water to uses in distant areas, destruction of fish and wildlife habitat and loss of recreational opportunities (Gould 1989), but courts generally will not deny transfers because of these indirect effects (see, for example, *Ensenada Land and Water Ass'n* v. *Sleeper, N.M.* Ct. App. 1988).
25. Early water transfers of agricultural water to urban use are often characterized by the phrase 'buy and dry' to signify the fact that once the water was transferred the land was allowed to simply dry out, with little effort to reclaim the land and plant it with native grasses that could sustain themselves in the arid conditions that characterize much of the western US (see, for example, Schempp 2010).
26. Water banks have played a modest role in encouraging the growth of water markets. 'Water banking is emerging as an important management tool to meet growing and changing water demands throughout the United States. . . . The overall goal of a water bank is to facilitate the transfer of water from low-valued to higher-valued uses by bringing buyers and sellers together' (Clifford et al. 2004, p. 12–15).

27. Indeed, Wyoming specifically prohibits the transfer of any water rights beyond its historic consumptive use (Wyo. Stat. Ann. § 41-3-104(a) 2009).
28. As one noted article has famously observed in a similar context 'stationarity is dead' (Milly et al. 2008, pp. 573–4).
29. While there may be an argument for extending the seasonal right to the historic extremes, this would seem unfair to other users, since the historic extremes, that is, the earliest and latest irrigation dates historically observed, will ultimately become commonplace, thus leading to significant increases in average annual water use.
30. In 2005, domestic per capita use in California was estimated to be 124 gpm, and in Colorado 121 gpm (Kenny et al. 2009)
31. See, for example, 'Transactions', The Water Strategist, December 2010, pp. 5–6 (listing transactions in California for 1993 acre-feet of water at $5850 per acre-foot, and in Colorado for 372 acre-feet at between $10 187.50 and $13 636.36 per acre-foot).
32. Every western US state recognizes that water is held by the state for the benefit of its people (see, for example, Colo. Const. art. XVI, § 5; Wyo. Const. art. 8, § 1).

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Conclusion

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INTRODUCTION

This book demonstrates that international and national recognition of water scarcity and quality issues has led to action. Some of this action involves policy, some involves practice and some involves the development of information systems to inform policy and practice. Included in these information systems are water accounting systems that are being applied to varying degrees in different geographic locations. Each water accounting system discussed in this book aims to inform decision-making. However, the decision-makers and the decisions differ across systems.

Are these systems conceptually sound? What are their objectives? To what extent are they complementary, and to what extent do they compete or overlap? Has their development 'piggy-backed' on the development of another system or occurred independently? Are they practical? Do they serve their intended purpose(s)? Should there be one water accounting system only, or can systems co-exist? These questions are all addressed throughout the preceding chapters, and we provide a brief overview of some of the key findings in this chapter. We do not propose to thoroughly analyse the systems in this concluding chapter. It is far too early in the life-cycle of the various water accounting systems to undertake something so complete. Rather, we provide some preliminary thoughts in relation to each of the questions and trust that future research will address the answers more comprehensively. To conclude this chapter and the book, we conjecture what the future holds for global acceptance of one or more water accounting systems, and how that might be achieved.

In the remainder of this chapter, we briefly summarize some of the key strengths and weaknesses, as we see them, of the water accounting systems described in this book. We do so under headings matching our questions above: theoretical underpinnings, complementarity and substitutability of systems, interrelationships between systems, systems practicality and usefulness. Because the systems are still undergoing development, our summary and comparison is necessarily partial. We hope that it will trigger further debate in the interests of progressing water policy, management and reporting to achieve, inter alia, important economic, sociopolitical and environmental decisions. Following this summary analysis, we turn to questioning whether there should be one system of water accounting only, or whether systems can co-exist.

In concluding, we propose an approach that may lead to globalization of standardized water accounting, thereby facilitating consistency, transparency, comparability and rigour in reporting internationally, while also achieving efficiencies in setting standards for water accounting and their adoption and enforcement. This is particularly important given the role water accounting can play in mitigating or resolving conflict (especially in relation to trans-border flows – see Part III Chapters 12 and 13: Pretorius and Turton, and Allan) and in sustaining the environment and social and public policies, infrastructure and culture (see Part III Chapters 10 and 11: Clark and Woods, and Muller).

A PARTIAL ANALYSIS OF WATER ACCOUNTING SYSTEMS

Theoretical Underpinnings

The systems discussed in this book all have an objective, either explicit or implicit, and they are developed with the intention that they will serve useful purposes in aiding decision-making of some sort. At the upper extreme of explicit conceptual underpinning and theoretical development is the General Purpose Water Accounting system discussed in Part I Chapter 1 (Slattery et al.) and Part II Chapters 6, 7 and 9 (Hughes et al., Andreu et al., and Mungatana and Hassan). This system has a complete and comprehensive conceptual framework that includes a Statement of Water Accounting Concepts dedicated to explaining the objective of the system as being to assist decision-making by parties who are unable to command the production of information about water that they need for those decisions (BoM 2011). It also includes other Statements of Water Accounting Concepts that explain such matters as the qualitative characteristics that water accounting should possess if it is to serve that decision-usefulness objective, the elements of water accounting reports, when those elements should be recognized in water accounting statements, how the elements should be quantified, disclosure of relevant information in notes and whether and by whom water accounting information should be assured.

None of the other systems examined in the book has a conceptual framework that is as clearly and explicitly developed from a conceptual basis as General Purpose Water Accounting, but it is clear that they have been developed applying logical sequencing of argument to achieve their objectives.

The role of the System of Environmental-Economic Accounting for Water (SEEAW) is to provide information that individuals and organizations (including governments and regulatory authorities) can use if they extract, manipulate and use that information from SEEAW tables to inform a range of assessments and decisions. Consistent with this objective, the final SEEAW product is a series of tables containing information that can be drilled down to the individual industry, basin, state, organization or individual irrigator level from aggregated information. Since the objective is primarily statistically and research oriented rather than directed towards the final communication of information to guide decisions, the objective is achieved as long as the information reported in SEEAW accounts/tables has some potential end use.

The information reported in the SEEAW and the General Purpose Water Accounting systems are both intended to serve decision-making purposes, but are intended to achieve different endpoints. SEEAW produces a series of tables linking hydrological data and economic activity. In contrast, General Purpose Water Accounting is a communication device that includes formatting information to present it in a manner that also guides user decisions.

Water Footprint Accounting has been designed to quantify and locate the water footprint of a process, product, producer or consumer or to quantify in space and time the water footprint in a geographic area (see Part I Chapter 3, Hoekstra). At the International Water Accounting: Effective Management of a Scarce Resource conference in 2010, discussants questioned the system's ability to achieve what is perceived as its objective. That said, participants discussed two Water Footprint Accounting objectives. One is to raise awareness of the water intensity of producing particular products in particular geographic locations during specified periods. The other is a higher-order objective: to inform assessments that will influence decisions about whether to produce or buy particular products. In relation to the former, Water Footprint Accounting was seen by some to be a relatively logical system that could serve its purpose, as long as contextual information was provided. In relation to the latter, conference participants expressed concerns about whether the system would be effective in assessing the environmental and social responsibility attached to the consumption of water in producing particular products, even if additional information were to be provided. Examples of the issues debated include (1) if a choice is between producing a water-consuming product in a region where employment is necessary to generate social, economic, political and cultural benefits that significantly outweigh the environmental impact of using water in the production, the water footprint approach can lead to poor decisions; (2) the system does not differentiate between 'good' and 'bad' use of water due to water abundance versus scarcity; and (3) the system does not differentiate between water of different quality, the opportunity cost of water or whether water is recycled through the production process. Again, this can lead to perverse decisions if water that is non-potable is included in the water footprint of products; the water otherwise could not be captured and used for human, environmental or other needs; or the water is used in a system that then collects the water again and recycles it for other uses.

The water accounting system developed at the International Water Management Institute (IWMI WA) is very similar in concept to General Purpose Water Accounting. A key difference is that IWMI WA does not require an accounting for rights and other claims to water. Rather, it focuses solely on physical H_2O. Primarily targeted at basin management, it utilizes a standard method to account for the amount of water available, used by various sectors and the value derived from the use to promote understanding of basin water use (see Part I Chapter 4, Karimi et al.). The fundamental purpose of this system is to assist in identifying effective strategies for water savings and productivity. The system seeks to facilitate water-related discussions between water professionals and non-water professionals.

Similar to other systems described, IWMI WA adopts a water balance approach but it aims to deal with complexities in hydrology brought about by use, reuse and storage of water by utilizing water consumption/depletion concepts (for example, evapotranspiration, flows to sinks) rather than water withdrawals. Just as the General Purpose Water Accounting system requires clear specification of a water report entity and a specified reporting period and report date, IWMI WA requires identification of a domain bounded in three-dimensional space and time. Thus, it invokes the 'entity' concept whereby water withdrawals and recycling are internalized unless they cross domain boundaries. This system's logic is very similar to that of General Purpose Water Accounting.

Complementarity and Substitutability of Systems

We are aware that SEEAW has been regarded in some circles as a water accounting system in competition with General Purpose Water Accounting. However, while both may require the recording of overlapping information, they differ markedly in terms of the presentation of their output. SEEAW yields tables that serve as a source for research purposes and for finding information to then input to reports or ratios or other measures. The tables document data in the same manner that national Bureaus of Statistics, or their equivalents, with table data pertaining to financial and economic information such as production and income levels across the nation or within the nation (for example, categorized by state, province or industry). In contrast, General Purpose Water Accounting requires the reporting of data in statements and notes with formats that are designed to facilitate decision-making. General Purpose Water Accounting reports may report some of the same data as would be reported under SEEAW, but their presentation is significantly different and takes the SEEAW data to the stage where it becomes information by virtue of the manner in which it is presented. As such, the two systems should be seen as complementary.

In contrast, Water Footprint Accounting does not overlap at all with SEEAW or General Purpose Water Accounting. It is conceivable that Water Footprint Accounting could complement either system in understanding the use of water within particular industries and the flow-through effect on the water consumed to produce particular products. However, it is unlikely that it would be used often in this manner because both SEEAW and General Purpose Water Accounting tend to focus upon the producing unit rather than the product itself. As such, Water Footprint Accounting is likely to be neither a complement nor a substitute for SEEAW or General Purpose Water Accounting. It is a tool intended to calculate freshwater consumption in the production of goods and services. Water Footprint Accounting may well draw upon the same internal systems for capturing information about water use, with the data being classified and reported according to its use in particular processes for SEEAW or General Purpose Water Accounting, and according to the product it is used to produce for Water Footprint Accounting.[1]

IWMI WA is very similar to General Purpose Water Accounting and can arguably form a subset of the latter system. If the IWMI WA entity overlaps perfectly with the water report entity of General Purpose Water Accounting, the latter system's Statement of Physical Flows and associated Notes, resembles the type of report that could be produced by IWMI WA. Similarly, the General Purpose Water Accounting Statement of Water Assets and Water Liabilities would incorporate balances relevant to IWMI WA. The key differences between the approaches appear to be that (1) General Purpose Water Accounting incorporates an accruals concept, thus water rights and other claims to water are included whereas they are not part of the IWMI WA approach; and (2) IWMI WA yields performance indicators (including indicators that relate water to the physical mass of production or the economic value of production per unit volume of water) that could be incorporated under General Purpose Water

Accounting, but which are not necessarily required under that system. As such, much of IWMI WA overlaps a portion of General Purpose Water Accounting, and some of the approach extends that portion. In this context, both draw upon data that could be recorded under SEEAW, but presented differently.

Part II Chapter 5 (Cote et al.) describes water reporting that enables mining companies to address the requirements of the Global Reporting Initiative (GRI) system of reporting, SEEAW and General Purpose Water Accounting. We have not described this as a separate system in this book, but rather as an application of various systems. This is because it provides information to satisfy the requirements of these systems and represents, thereby, a modification of systems through the incorporation of other systems.

Interrelationships between Systems

IWMI WA was developed prior to any other systems discussed in this book (see Molden 1997; Molden et al. 2001). Its concepts are incorporated in varying ways within General Purpose Water Accounting and SEEAW. However, the IWMI WA influence on these systems has been indirect rather than incorporated directly and consciously into the logic underpinning these systems.

SEEAW and General Purpose Water Accounting were developed around the same time, with much of that development occurring during 2007 through 2011. However, the systems were developed quite independently and using different approaches. SEEAW was developed through the United Nations (UN), whereas General Purpose Water Accounting was developed entirely within Australia, and by individuals not involved in SEEAW development. Thus, even though the systems' development teams had general awareness of each other's approach, they did not draw upon each other's work to develop their systems.

Similarly, Water Footprint Accounting is a very different system from any of the others described in this book. It was developed in the early 2000s by Professor Arjen Hoekstra at UNESCO-IHE and subsequently at the University of Twente, in the Netherlands. This development occurred independently of the UN and Australian input and does not draw upon their logic.

In contrast, the Australian minerals industry system described in Part II Chapter 5 (Cote et al.) developed rapidly between 2007 and 2010, drawing from work that occurred in developing a draft water accounting conceptual framework to underpin General Purpose Water Accounting, and the succeeding Preliminary Australian Water Accounting Standard and the

Exposure Draft (see Part I Chapter 1). As such, the Australian minerals industry system of reporting is a modification of General Purpose Water Accounting that incorporates elements of SEEAW and GRI. According to individuals involved in the development of General Purpose Water Accounting, SEEAW and IWMI WA, GRI was considered during their development, but it was not explicitly incorporated into their logic or requirements.

System Practicality

The practicality of all of the water accounting systems described in this book is currently being tested and several chapters report on this testing. Not surprisingly, the various forms of water accounting are often criticized for data inaccuracy, particularly in reporting groundwater volumes or modelling water in remote and relatively uncharted territory. These issues are analogous to the issues faced in financial reporting, where there is significant subjectivity and uncertainty involved in calculating or modelling the value of untraded stock options, depreciation of buildings, the value of land under roads, goodwill, doubtful debts and the like.

Pilot tests throughout the General Purpose Water Accounting conceptual framework and exposure draft development have proved that the system can be implemented in practice by different types of organizations (for example, a water utility and a corporate water user). Furthermore, international testing reported in Part II Chapters 5, 6 and 7 (Cote et al., Hughes et al. and Andreu et al.) demonstrates that the system is internationally applicable. It also reveals that the system produces information that is useful to managers as well as to the external parties to whom it is directed

That said, one commonality to the pilots and international applications of General Purpose Water Accounting is that they highlight inaccuracies in quantifying volumes of water and the sources or destinations of changes in water. This is a problem common to all the systems discussed in this book. The pilots also highlight that some relevant information is not currently captured (for example, water value). It should, of course, be noted that General Purpose Water Accounting requires the recording, reporting and assurance of some information that is not commonly otherwise collected and reported to external parties. Once a system is bedded down and its importance understood, it is likely that the imperatives of improved reporting to external stakeholders will drive a market for better modelling and metering and inclusion of information regarding water value. The biggest issue related to General Purpose Water Accounting identified at the 2010 Prato conference is defining the water report entity and the boundaries of water accounting to prevent abuse of the system.

As a UN system, SEEAW is now being applied to varying degrees in many countries throughout the world and in Part II Chapter 8, Gan et al. describe modifications to SEEAW to suit its implementation in China. SEEAW suffers more extensively from similar data collection and inaccuracy issues than General Purpose Water Accounting, due to the greater scale to which the system is applied. These issues are evidenced by the fact that preparers of SEEAW accounts have, in many cases, been unable to provide some of the information required for SEEAW. Like General Purpose Water Accounting, until SEEAW becomes a more generally accepted and applied system, this is likely to remain the case. At the 2010 Prato conference, participants questioned countries' ability to obtain all the data required by SEEAW; they also queried how the information is being used and the extent of its adoption.

IWMI WA has similar application issues to General Purpose Water Accounting, but because it is limited to water and not rights to water, some application issues do not apply. Use of remote sensing instead of flow measurement and field data can mitigate some practical constraints, particularly for large transboundary basins. However, as Karimi et al. (Part I Chapter 4) acknowledge, satellite-driven data are also associated with uncertainties that can affect the accuracy of measures. As with the other systems, issues of interpretation were raised at the Prato conference. In relation to IWMI WA, issues include concerns about the potential to confuse water efficiency with overall productivity when linking land use with water use. Also, while acknowledging the role of remote sensing for information collection and other advances in measurement, the authors recognize that the data crisis is as large as the water crisis.

Water Footprint Accounting has also been criticized for practical application difficulties. In particular, assessing the amount of water consumed in various stages of production is difficult when there is a need to evaluate such matters as how much water is stored in the sources of the product (for example, how much water is consumed by cows, either as water or in feed, that produce milk that is used to produce cheeses or other milk products whose water footprint is being estimated). In many ways, the issues relating to the reliability of volumes estimated for the purposes of Water Footprint Accounting are an order of magnitude greater than those related to either SEEAW, General Purpose Water Accounting or IWMI WA.

System Usefulness

The ultimate test of a water accounting system is its usefulness. At this early stage in the water accounting discipline's evolution, system usefulness is difficult to assess, particularly since some systems are not in general use and the first complete reports have yet to be published for some systems. However, the testing in a range of countries that is reported in Part I (Karimi et al.) and Part II (Cote et al., Hughes et al., Andreu et al., Gan et al. and Mungatana and Hassan) indicates that General Purpose Water Accounts, SEEAW and IWMI WA provide information that is useful for decision-making. We are aware through our own networks and activities of research that investigates whether water accounting reports will assist investment decisions and other decisions involving assessments of the operating risk of firms with water-intensive operations and of the cultural impact of adopting alternative water reporting systems within organizations. Most of this research is preliminary at the time of writing.

In Part I Chapter 3, Hoekstra also argues that application of Water Footprint Accounting is useful. While product and national water footprint case studies have been devised and the concept of business water footprints are being promoted, at this stage we are unaware of any application of the system and use of its output for decision-making. As such, we are unable to comment upon its usefulness, other than to caution users that it is important to contextualize the water footprint of any product for reasons discussed earlier in this chapter: the fact that a product has a large water footprint is not necessarily bad if, for example, that water is non-potable, was recycled, and was sourced from a region of water abundance.

We consider water accounting system usefulness from a more holistic approach in Part III of the book. Chapters 10 through 14 address questions such as: What is the role that water accounting can serve in intergenerational equity and in conflict mitigation and resolution? What role can water accounting play in relation to corporate sustainability, the public interest and sound water management? What constrains the potential for water accounting to serve this role?

Managing water resources responsibly requires the adoption of a long-term decision horizon since water management decisions made today will affect future generations. In Part III Chapter 10, Clark and Woods introduce us to the notion of a politically independent planetary trust or pension fund as an institutional solution to governing and making decisions from an intergenerational equity perspective. They recognize that the Murray Darling Basin Authority (MDBA) has been established to serve such a role in relation to water in Australia. One of the MDBA's roles is to balance the current and future rights to water of consumers, producers and the environment. To do so, the MDBA can benefit from using and reporting appropriately prepared and presented water accounting reports that recognize rights and obligations relating to each claimant. In this regard, water accounting systems can contribute to the balancing of current and future generations' interests in water.

Consistent with the Clark and Woods description of water issues giving rise to intergenerational conflict, the remaining chapters in Part III all relate to conflict and the role that water accounting can play in its mitigation or resolution. Inevitably, conflict is related to risk of some sort, which may be at an international or national political, organizational or other level. Legally, international property rights over water are established to control for certain risks, and international water course management agreements are critical to protecting the rights of states affected by trans-border flows. In Part III Chapter 13, Allan assesses the specific role that water accounting can play in inter-state dispute avoidance. Using General Purpose Water Accounting as an exemplar, he identifies the system's principles that are shared with existing treaty practice and the broader principles of the law on international watercourses. He explains that the core elements of water accounting (data exchange, harmonization and transparency) are used at international levels as part of efforts to manage watercourses, avoid disputes and manage differences in ways that facilitates inter-state cooperation. In doing so, he also cautions that water accounting is only one tool, but an important one, in the armament for dispute resolution or mitigation. He outlines that its effectiveness is conditional upon many factors, including agreement on water accounting approaches, property right entitlements and a willingness to engage.

While not disagreeing with the tenor of Allan's assessment of the role of water accounting, Muller (Part III Chapter 11) focuses upon the fact that water accounting is not necessarily neutral and can therefore be used 'to promote sector-specific interests and to advance policies that are not supported by the communities concerned'. In particular, he establishes the danger that power and capacity asymmetry can lead to standards being imposed only on weaker parties. He thus provides a call for continued efforts to improve water accounting and its use in both physical and economic terms so that societies can manage successfully the growing pressures that they place on their water resources. He explains that because corporations are often both the source of pressures and the drivers of innovations to address them, the engagement of these corporate actors in the water accounting process is important if systematic, sustainable solutions are to be found, both in terms of water accounting and water management. He also explains the importance of ensuring that water accounting frameworks are feasible and reflect societal capability, address social and economic dimensions as well as water and environmental dimensions and do not unnecessarily constrain sustainable development opportunities. Finally, he concludes that given the importance of high-quality governance in water resource sustainability, a pragmatic approach would be to develop water accounting as a contribution to sustainable management, supporting public policy formulation and decision-making, much as is starting to happen in some communities.[2]

Acknowledging that water is a risk to the operation of many organizations' activities and services and that it is essential that internal and external stakeholders understand such risks, Pretorius and Turton describe a general model of water risk in Part III Chapter 12. This model is applicable to a single firm, an industry, economic sector, or the state itself. They then present an argument for the role of water accounting in identifying and clarifying eight generic types of risk that are applicable to water accounting and to organizational risk. These risks are value chain risk, physical risk, financial risk, operational risk, political risk, regulatory risk, reputational risk and risk associated with scale. Consistent with other chapters in Part III, Pretorius and Turton explain the role of water accounting as a tool for clarifying and reporting risk, and thereby serving as a tool for conflict mitigation or resolution.

In the final chapters in Part III, Lund, and Squillace, draw upon the issues described in prior Part III chapters to explain how water accounting can improve water management, markets and governance, despite its lack of neutrality. They do so in the context of the western US, where water scarcity causes issues relating to property rights. They describe how water accounting can assist by providing useful information for quantitative specifications in rights, contacts and agreements; and by providing useful information that, inter alia, reduces uncertainty risk and improves decision-making and the discharge of accountability. Lund describes the state of water management and water accounting in California, where demand for water is increasing and water accounting is improving over time, as 'sparse and rudimentary'. He explains that more complete and formal water accounting will become increasingly valuable in resolving water conflict. However, like Muller in particular (Part III Chapter 11), Lund recognizes that there are political, institutional and practical impediments to water accounting improvements in California. In particular, he describes 'combat accounting', where particular parties seek to alter or manipulate water accounting systems to serve their interests, for example by inflating or deflating estimates of water availability or use to favour them at others' expense. As he mentions, '[l]ike the law, all parties have an interest in a strong, reliable accounting system, but also have particular interests in evading or bending these systems'. In California, combat accounting has led to long exemptions of groundwater from the water rights permit system, for example. In conclusion, Lund offers suggestions for ideal outcomes from improvements to California's water accounting system. He also proposes that the force of progress, through improved water measurement and modelling technologies, is likely to provide a means for more standardized and complete water accounting so that physically-based calibrated model representations might become authoritative substitutes for more expensive and potentially less reliable field measurements that also require (not always forthcoming) land owner cooperation.

Squillace's final chapter of Part III (Chapter 15) examines an issue referred to in numerous chapters: measurement accuracy. The chapter examines practical constraints upon measurement accuracy for diversions and storages, personal incentives to perpetuate measurement error in certain contexts and the individual and aggregate effects of measurement error. As he comments:

> [e]ngineering studies have periodically assessed the accuracy of flumes and other water measuring devices both in the lab and in the field. But little work has been done to assess the costs and benefits of more accurate measuring devices and more careful supervision of those responsible for ensuring the accuracy of these devices in the delivery of water.

Focusing upon western US measurement approaches, Squillace points out that measurement errors might involve small misappropriations of water in relation to individual property rights, but in aggregate these errors can be significant, particularly since there will be a bias towards their understatement of the amount of water extracted and this has a particular impact in the case of the western US, which is renowned for its system of allocating water by 'prior appropriation'. He examines the role that water accounting, however implemented, can play in establishing property rights and accountability for the discharge of property rights. In doing so, his analysis covers technical, policy and governance issues relating to measurement accuracy. It offers some insights into how accurate information about water diversions and use might be gathered, and how that information might be used to promote a better system for managing limited water resources.

WATER ACCOUNTING AS A SINGULAR SYSTEM?

One question we are often asked is 'Which water accounting system is preferred?' To this, our reply is generally that the best system is the system that provides the most relevant information that is reliable, representationally faithful, comparable and usable. This might vary according to the decision to be made. In this sense, water accounting is akin to accounting for money, where at least five general systems operate:

1. Financial accrual accounting, which is the basis for periodic reporting to external parties by most private sector entities and public sector entities in many countries.
2. Financial cash accounting, which is used for external and internal reporting, given the importance of cash to meet debts and honour financial payment expectations of owners.
3. Management accounting, which is used by managers to report internally, and can be manipulated to suit whatever purpose management wishes to achieve.
4. Tax accounting, which requires preparation of periodic taxation returns in accordance with taxation laws.
5. Government economic statistics, which requires reporting of matters such as the balance of payments, gross domestic product and the like. This accounting complies with international, national, or more localized rules and formulae specific to government reporting.

These monetary accounting systems are all different, but each is appropriate and better suited to different purposes. For centuries they have co-existed, and we would argue that the same is likely to occur in relation to water accounting. At a minimum, it is to be expected that two water accounting systems will eventually be applied by most organizations: external water accounting and management (internal) water accounting. Our book focuses upon external water accounting since managers have the ability and power to decide for themselves what information they require for internal purposes and can obtain that within their organizations.

GLOBALIZATION OF WATER ACCOUNTING: STANDARDS, ADOPTION AND ENFORCEMENT

All of the water accounting systems described in this book have been implemented, at least partially, in more than one country and all are suited to multinational application. This raises the possibility that various water accounting systems will be modified in each country and become internationally internally inconsistent and incompatible if are not regulated through international standards. Just as global financial reporting is now shaped through International Financial Reporting Standards developed by the International Accounting Standards Board in order to provide a consistent, high-quality set of financial accounting standards, is there a case for international water accounting standards? If so, should international water accounting standards deal with only one water accounting system? Who would encourage or enforce their adoption? What institutional framework would be appropriate?

As reflected in Globalisation of Accounting Standards (Godfrey and Chalmers 2007), stakeholders in various countries claim that the benefits of global financial accounting standards include increased comparability of financial statements, clearer and more transparent establishment of property rights, kudos from becoming more developed and aligned with Western methods of reporting, transfer of political power and greater access to capital markets, especially foreign and institutional investment. From the preceding chapters, it is clear that analogous claims could apply to water accounting.

When nations join the movement towards global financial accounting standards, this generally is justified on economic or political grounds. The move to more globally accepted financial accounting standards clearly is seen as a mechanism for economic transformation, particularly for developing countries where the reporting improves financial practices and expertise. In this regard, the International Organization of Securities Commissions (IOSCO) played a critical role in promoting international accounting standards. IOSCO's recommendation in May 2000 that its members allow multinational companies to use international accounting standards for cross-border listings and capital raisings was a catalyst in gaining acceptance for a global set of accounting standards. It also provided the political ammunition for international accounting standards acceptance in various countries (ibid.).

Could similar arguments and interventions apply in relation to water accounting? And if so, would water accounting standards necessarily apply to only one system?

To answer this question, we draw upon some of the experience relating to the globalization of financial accounting standards. This relatively recent phenomenon that gained momentum during the late 1990s and early 2000s can be regarded as part of a globalization movement that includes economic, cultural and corporate governance aspects. Governments and national standard-setters believe that embracing global accounting standards will open up capital markets and either attract, or restrict the loss of, foreign investment. Typically, embracing international accounting developments post-dates a country crisis and is a legitimizing or reputation enhancing action. This is reflected in the growing acceptance of international accounting standards in China, India, Japan and South Africa to promote economic reform; the US working closer with the International Accounting Standards Board subsequent to its financial scandals at the start of this century; and Italy eventually embracing harmonization to enhance its reputation in the accounting standard-setting community (ibid.).

The circumstances surrounding the development and implementation of water accounting are similar. Whereas the Asian financial crisis and the global financial crisis and several high-profile accounting scandals played a role in relation to financial reporting, severe droughts, other extended periods of water scarcity and water abundance resulting in floods have afflicted many nations and caused water crises. In turn, these water crises have generated economic, social and political hardship, and international and intra-national conflict. The world is looking for solutions to water-related issues. In doing so, there is increasing recognition that water accounting can be part of that solution.

However, the financial accounting and water accounting circumstances differ in several significant ways. For example, no system of water accounting has been fully adopted for any extended period by organizations in multiple countries – or, indeed, any individual country. Hence there is no long national history of national standard-setting and enforcement to draw upon and no history of international collaboration in the development of national standards as existed with financial accounting. This lack of experience in standard-setting and collaboration might be seen as a challenge to the development of a global approach to water accounting standard-setting. Alternatively, it can be seen as an advantage because the absence of entrenched differing approaches and standard-setting cultures might facilitate the development and adoption of a single international approach to water accounting standard-setting.

At a more philosophical systems level, key issues relating to the potential development, adoption and enforcement of global water accounting standards, as with global financial accounting standards, could revolve around the adoption of a principles versus a rules approach to standardization. For example, General Purpose Water Accounting standards will be principles-based, requiring the water accountant to exercise his or her professional judgement in applying general principles to determine what should be reported and how, within guidelines that are strategically linked to the objective of providing information to assist decision-making by external stakeholders. It is to be expected that, as occurs with financial accounting, some countries are more rules-based in their culture, and will seek more detailed and prescriptive rules for standards. Presumably, these issues could be handled by an international water accounting standard-setting body with an appropriate composition of culturally sensitive individuals drawn from around the globe. Perhaps the approach would differ for different water accounting systems if the international water accounting standard-setter were to take responsibility for setting standards across multiple systems, such as General Purpose Water Accounting, SEEAW, IWMI WA and Water Footprint Accounting, or any combination thereof.

Because different water accounting systems are designed to serve different purposes, it is conceivable that the same water accounting standard-setting body could set standards for multiple systems. However, many other issues are not so straightforward. For example, if an institutional framework for the setting and enforcement of water accounting standards were to be developed and implemented, many issues would need to be considered:

1. How can international acceptance of a global body responsible for the development of water accounting standards be gained?
2. Would comparable and consistent water accounting reports necessarily result from the globalization of water accounting standards?
3. Would it be a role of the standard-setter to provide detailed interpretative guidance?
4. From what countries should membership of a global body be drawn?
5. How should the standard-setting exercise be funded? On a user pays basis? What positive or perverse incentives would such arrangements generate?
6. What enforcement approach(es) would be appropriate, particularly for countries where water management practices are not well developed? Would an agreement be struck between nations and the international standard-setting body or its oversight body?
7. What role would be played by organizations such as the UN? The World Bank? The World Meteorological Organization? National bodies and governments?
8. How would capacity be built to enhance adoption throughout the globe? Whose responsibility would it be to educate and train the initial cohorts of international water accountants? In a similar vein, a key issue for many countries emanating from the adoption of International Financial Reporting Standards in the early 2000s was the training of staff in both accounting firms and reporting entities to facilitate the standards' adoption and assurance. In South Africa, for example, compliance with International Financial Reporting Standards was outsourced to external audit firms that established International Financial Reporting Standards conversion consulting businesses (an interesting twist of the notion of auditor independence!) (Godfrey and Chalmers 2007). In Australia, resources are already being developed to educate new water accountants through higher education and continuing professional development courses for individuals in both accounting and water-related disciplines.

While the existence of trans-border flows and increasing removal of global barriers make a global water accounting language appealing, international differences between economic, social and political characteristics raise questions concerning the ability of all countries to enforce an identical set of regulations.

Even drawing upon the vast experience of financial reporting standards globalization, what cannot be forecast with certainty is whether there is a future role of international water accounting standards. The survival of an international standard-setter would depend on it becoming, and then remaining, relevant and respected relative to each country applying its standards. This would require commitment from countries to adopt the standards, probably demonstrated in financial terms by nations at least partially resourcing the standard-setting body and its regulatory mechanisms. It would require diffusion of technical expertise to meter or model water, capture water data and classify, quantify and report that data in meaningful ways. It would also demand a respected enforcement mechanism that recognizes the different levels of skills and need for water accounting in different parts of the world. It will be interesting to observe, in another decade, how far the world will progress in relation to globalizing water accounting practices.

CONCLUSION

The past decade has seen enormous attention and effort focus upon the management of water and its economic, environmental, social and other consequences. Severe droughts, other extended periods of water scarcity, fears of global warming and sustainability issues associated with population growth and its demands upon water resources have all served to focus attention on the world's most precious resource. Out of necessity, systems of water accounting have developed to inform stakeholders about how water has been managed. With this information, stakeholders will make important decisions about matters of local, national and international importance. Whether to invest in an organization or country will be influenced by a greater understanding of the organization's or country's exposure to water supply risks. Water allocations and pricing will be informed by information about the demand and supply of water across various regions and industries. Community infrastructure will depend upon knowledge of water quality, distribution and flows. Underpinning all of this knowledge and understanding will be a discipline that marries the best of financial accounting, statistics, hydrology and engineering: water accounting.

We look forward to revisiting the debate about which water accounting system(s) will survive the tests of time, and whether there will ever be international water accounting standards relating to systems adopted in their entirety by nations around the globe. While progress has been substantial in terms of water accounting systems development, it is important to acknowledge that this is but one step in the right direction for protecting water and ensuring economic, environmental, social and cultural sustainability at national and international levels. This book provides a preliminary understanding of the significance of that step.

NOTES

1. These two approaches mirror the financial management accounting systems: process costing and job costing.
2. Australia's development of General Purpose Water Accounting and the UN development of SEEAW can be seen as part of this governance approach for their respective communities.

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