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FAO WATER REPORTS

43

Water accounting and auditing
A sourcebook

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Water accounting and auditing - A sourcebook

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by
Charles Batchelor
FAO consultant

and
Jippe Hoogeveen, Jean-Marc Faurès and **Livia Peiser**
FAO Land and Water Division

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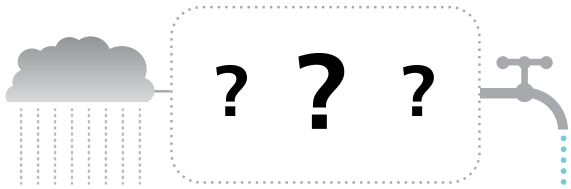
Preface

In some cases, the question in the cartoon of Figure 0.1 is relatively easy to answer. The source of water could be a well or a spring. Water could be pumped from this source to an appropriately-located storage tank in or near the home and, all being well, water would flow under gravity from this storage tank to the tap(s) in the home. So, in this case, this is how water reaches the home and the costs incurred are: 1) Capital costs of constructing the system; 2) Recurrent cost of Operation and Maintenance (O&M) such as pumping costs, repair costs; and 3) the cost of routinely testing the quality of the well or spring water. This is about as simple as a piped water-supply system can be. However for most water users, delivery of water from "rain clouds to the home" on a secure, reliable and predictable basis is more challenging.

FIGURE A
How do we get water?



In many regions of the world, sustainable and reliable delivery of water (or rather water services) to homes at the same time as protecting environmental flows, has become increasingly complex and problematic. Particularly if overall demand is outstripping supply, the delivery of water services is often less about engineering, although engineering is still required, and more about politics, governance, managing and protecting sources, resolving conflicts about water, ensuring rights to water are respected, and so on. It is also about understanding and monitoring what is going on between the rain clouds and the water users. This is where water accounting and auditing can play a crucial role.

The rationale behind this water accounting and auditing sourcebook is that scope exists worldwide to improve water-related sectoral and inter-sectoral decision-making at local, regional and national levels. Improvements can often be initiated by basing decisions on 'best-available' information, evidence and analysis – rather than intuition, assumptions and guesswork.

Of course, it would be naïve to believe that improvements in water governance or policy-development will follow automatically and seamlessly from water accounting and auditing. The collection, evaluation, analysis and interpretation of biophysical and societal information that is central to water accounting and auditing is subject to uncertainty and professional biases and, as behavioural scientists are quick to point out, irrationality. However, mutually-supportive water accounting and auditing has much to offer as a practical approach to: 1) Assembling and checking the veracity of information from multiple sources; 2) Analysing, modelling and interpreting this information; and 3) Assembling robust evidence to support decision-making, policy development and new courses of action.

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Acronyms and abbreviations

CA	Comprehensive assessment
CBO	Community-based organization
DEM	Digital elevation model
DFID	Department of International Development, United Kingdom
EPA	United States Environmental Protection Agency
ET	Evapotranspiration
EU	European Union
FRIEND	Flow Regimes from International Experimental and Network Data programme
ICID	International Commission on Irrigation and Drainage
FAO	Food and Agriculture Organization of the United Nations
GoUK	Government of the United Kingdom
GIS	Geographical Information System
GLUE	Generalised Likelihood Uncertainty Estimation methodology
GPS	Global Positioning System
GWP	Global Water Partnership
HEM	Hydro-economic model
HRD	Human Resources Development
HRU	Hydrological resource unit
INBO	International Network of Basin Organizations
IE	Irrigation efficiency
IT	Information technology
IWMI	International Water Management Institute
IWRM	Integrated water resources management
LA	Learning alliance

LCCA	Life-cycle cost assessment
LST	Land Surface Temperature
M&E	Monitoring and evaluation
MIS	Management information system
MSP	Multi-stakeholder platform
NGO	Non-government organization
OECD	Organization for Economic Co-operation and Development
O&M	Operation and maintenance
PES	Payment for environmental services
PCM	Project cycle management
QA/QC	Quality assurance/quality control
QIC	Quality improvement collaborative (type of stakeholder platform)
PEA	Political economy analysis
RIDA	Resources, Infrastructure, Demand/Access framework
SDCA	Stakeholder Dialogue and Concerted Action
SEEAW	System of Environmental-Economic Accounts for Water
SMART	Specific, Measurable, Achievable, Realistic, Timebound
SWAT	Soil & Water Assessment Tool
TWU	Total water use
UAV	Unmanned aerial vehicle
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WP	Water productivity
WWAP	United Nations World Water Development Report

About this sourcebook

PURPOSE AND SCOPE

Water accounting and auditing are recommended by FAO and others as being fundamental to initiatives that aim to cope with water scarcity (FAO, 2012). Therefore, the dual purpose of this sourcebook is to:

- Provide practical advice on the application and use of water accounting and auditing.
- Help users, plan and implement water accounting and auditing procedures and processes that best fit their needs.

This sourcebook is by no means the 'last word' in water accounting and auditing. Rather it should provide a good starting point for anyone or any organization that wants to: 1) Use water accounting and auditing for the first time; 2) Switch from using water accounting or auditing separately to using water accounting and auditing as mutually supportive processes; or 3) Review, and possibly refine, the approach to water accounting and/or water auditing that they are already using.

This sourcebook is neither a textbook nor does it try to exhaustively cover every possible approach to water accounting and auditing. Instead, the aim is that it should be a source of inspiration and encouragement to users who are interested in carrying out water accounting and auditing. Similarly it aims to instil confidence that, in most cases, combined water accounting and auditing can be carried out with active stakeholder engagement at a reasonable cost while still producing meaningful outputs that withstand scrutiny.

It is expected that most users will adapt their approach to water accounting and auditing so that it better matches their capacity and needs. Finally, this sourcebook does not provide a comprehensive review of how best to cope with water scarcity. For this information, readers are advised to turn to reports such as FAO's *Coping with water scarcity – An action framework for agriculture and food security* (FAO, 2012).

INTENDED USERS

The main target groups of this sourcebook are water professionals whose interests may well be on the biophysical or societal side of water resource management or water services delivery systems[1]. As a result, this report tries not to go into too much detail. Instead web links are provided to additional information that specialists may require (e.g. in relation to hydrology[2], political science or behavioural economics). This said,

[1] In this sourcebook the term biophysical encompasses: soils, geology, geomorphology, hydrology and hydrogeology and climate; flora, fauna and aquatic ecosystems; and, human settlement patterns and the physical results of past and present human activity (e.g. farming systems and other land/use management systems, water-related infrastructure and drainage or water treatment systems). The term societal encompasses formal and informal institutions; politics, the wider political economy and socio-political legacies; economics and behavioural economics; formal and informal legislation; and relevant social and cultural factors or norms.

[2] Throughout this sourcebook, the term hydrology also includes hydrogeology.

it is important to recognize that effective application of water accounting and auditing requires knowledge of hydrology, engineering, economics, anthropology, political science, statistics, spatial analysis, modelling and information management. As the likely implementers of water accounting and auditing programmes, the sourcebook has been designed to provide this specific target group with practical guidance.

There are some important considerations when recruiting or contracting specialists and building teams to implement water accounting and auditing programmes. To do a good job and produce outputs that stand up to scrutiny, it is advisable to recruit specialists who are willing and able to engage actively with:

- Specialists from outside their own discipline and to work in a multi-disciplinary environment. This can often be quite challenging because it involves learning new jargon and viewing issues from a number of different perspectives.
- Stakeholders and the wider public. To be meaningful, this often involves relinquishing control to stakeholders and being sufficiently humble to recognize that stakeholders usually have more first-hand knowledge of local-level idiosyncrasies than specialists and other 'outsiders'.

It is also important for individuals or teams responsible for implementing of water accounting and auditing to develop a culture of:

- Identifying and making full use of potential synergies between typical water accounting and auditing activities.
- Triangulating and double-checking outputs and findings from both water accounting and auditing.

HOW TO USE AND NAVIGATE THIS SOURCEBOOK

This sourcebook is divided into six sections, which can be summarised as follows:

Section 1: An introduction to water accounting and auditing This section introduces the concepts and terminology used. It also provides an overview of typical water accounting and auditing processes and highlights some of the characteristics, components and procedures that, in most cases, are important. Particular emphasis is given to synergies that can be derived from mutually supportive water accounting and auditing.

Section 2: Inception activities and stakeholder engagement. This section provides guidance on typical activities needed to plan a water accounting and auditing process. These activities include identifying issues and concerns; specifying domains of interest; and forming a multi-disciplinary team to undertake the water accounting and auditing. This section also touches on the potential benefits, or otherwise, of the wider engagement of civil society in water accounting and auditing.

Section 3: Water accounting. This section provides guidance on the use of a typical stepwise water accounting process and some of the methods and tools that are frequently used such as fractional and water balance analysis. Emphasis is on understanding and quantifying hydrological flows, fluxes and stocks in space and time. Particular attention is given to definitions and computation of water efficiency and productivity.

Section 4: Water auditing. This section provides guidance on the use of typical stepwise water auditing processes that are based on governance assessment and/or political economy analysis. Particular attention is given to the questions: How are decisions made? Who has the power to make decisions at different institutional levels? How this power is conferred and mediated?

Section 5: Information management and integrated analysis. This section highlights the fundamental importance of having an effective strategy for acquiring and managing information. Furthermore, it provides guidance on the use of multi-disciplinary analysis and modelling. It also highlights the benefits of using hydro-economic modelling; other integrated modelling approaches; and, scenario building and analysis as an integral part of evidence-informed causal analysis and strategy development.

Section 6: Outputs and outcomes. This section recognizes that the outputs from water accounting can often challenge deep-seated beliefs or received wisdom and that this needs to be taken into account when communicating outputs from a water accounting and auditing processes and when attempting to deliver positive outcomes.

1. An introduction to water accounting and auditing

1.1 THE CONTEXT

Increasingly water is a contested resource even in areas of the world that are relatively well endowed with water. The common perception is that *water shortage* (i.e. an absolute shortage of water supply in a specified domain) is the main reason for this state of affairs. However, the reality is that *water scarcity*, (i.e. an excess of water demand over available water supply) is by far the more important global challenge (FAO, 2012). The key difference between water shortage and water scarcity is that water shortage is driven primarily by biophysical factors (e.g. rainfall, land use, geology) and the status of infrastructural supply systems (e.g. their capacity, condition and operating rules). While water scarcity is dependent both on water shortage and the multitude of factors that drive water demand (e.g. population increase and per capita demand for water, economic growth, the need to protect aquatic ecosystems and so on) and the large numbers of political and socio-cultural factors that determine user-access to water of an acceptable quality (e.g. water rights, social exclusion, poverty, unreliable power supplies, wars or localised conflicts).

The media and many water sector professionals often refer to "a looming global water crisis". Others argue that the more predictable challenges, or potential water crises, can be avoided or mitigated by adjusting the way in which water is managed and governed (e.g. Moriarty *et al*, 2004; FAO, 2012). Their rationale is that, with good water governance and adoption of appropriate coping strategies, there is no reason why there should not be sufficient water to meet basic human and environmental demands on an equitable, sustainable and efficient basis, even in areas facing rapidly increasing water scarcity. However to achieve this goal, in many cases, it will be necessary for agriculture, which is the sector that consumes most water, to consume less especially in areas experiencing or facing increasing water scarcity.

A key to meeting these challenges is to make better use of water-related information when matching and adapting coping strategies to different biophysical and societal contexts. This is why water accounting and auditing should be a central element of any programme that aims to improve water security under conditions of increasing water scarcity.

1.2 RATIONALE FOR WATER ACCOUNTING AND AUDITING

The rationale for using water accounting and auditing is that it provides a solid framework for systematically acquiring, quality controlling and analysing water-related information and evidence[3]. In most cases this information and evidence will be interdisciplinary and derived from a wide-range of independent sources. It can be used for a number of purposes that include:

[3] At first glance the terms *information and evidence* appear to be interchangeable. However, in the context of water accounting and auditing they have different meanings. While all evidence is also information, not all information is evidence. The crucial difference is that evidence is used to prove or disprove a hypothesis, an argument or a contention.

- **Situation analysis** that identifies the causes of water-related problems and opportunities for solving these problems and, in so doing, matches biophysical and societal strategies and plans to the context and demands of different water users and uses in a specified domain.
- **Social and institutional learning:** An affirmative purpose of water accounting and auditing is to accumulate, generate and evaluate evidence and understanding related to, for example, the reasons why policies, interventions and practices produce desired outcomes in some contexts but not others[4]. In almost all cases, this includes understanding the social, political, and economic factors that may enable or constrain success of different strategies or plans.
- **Evidence-informed planning:** Intelligent use of many pieces of evidence, ideally from independent sources, can lead to incremental improvement in policies and programmes (Whitty and Dercon, 2013). Critically, there is also a higher probability that resulting interventions will stand up to scrutiny and be better adapted to the relevant political, societal and biophysical context. Information and evidence from water accounting and auditing can also serve as a basis for advocating significant changes to policies and programmes that expert consensus suggests should work but, when tested and evaluated, are shown not to.
- **Development and updating a common information base:** Stakeholder dialogue, planning and/or planning alignment are almost impossible if stakeholders are working with their own, differing, information bases. Yet, such a situation is very common (FAO, 2012).
- **Water allocation, regulation and conflict resolution:** As water scarcity increases, competition for water at all scales intensifies and conflicts become commonplace. Information and evidence are fundamental to effective stakeholder dialogue, resolving conflicts and establishing/implementing/refining long-term water regulatory agreements or frameworks.
- **Challenging factual errors or biased views:** Identifying and countering information and evidence are critical elements for mediating and conferring power within societal relations. Without correct information, society has no basis on which to challenge factual errors or biased positions.
- **Evaluating anecdotal evidence, expert opinion and folklore:** Many policies and practices are based on anecdotal evidence, expert opinion or folklore. Information and evidence from water accounting and auditing provides an unbiased basis for formulating policies and practices. In some cases, water accounting and auditing may confirm the veracity of, for example, traditional knowledge. In others, it may show that the relevance and utility of traditional knowledge has diminished.
- **Awareness-raising:** Water accounting and auditing can provide information, evidence, stories and other outputs that are affirmative, accurate and around which carefully targeted awareness campaigns can be designed and implemented. The aim is to move away from awareness campaigns and communication strategies that are based predominantly on wishful thinking and a simplistic search for quick fixes to what are often complex biophysical and societal challenges.

[4] In this context *learning* is considered to be an exploratory stepwise process that involves stakeholders working in concert with specialists, academics. In some cases, an element of action research may also be included with the aim of fostering innovation and/or adaptation.

1.3 WATER ACCOUNTING

1.3.1 What is water accounting?

FAO (2012) describes water accounting as the systematic acquisition, analysis and communication of information relating to stocks, flows and fluxes of water (from sources to sinks[5]) in natural, disturbed or heavily engineered environments. The somewhat sharper definition of water accounting in Box 1.1 recognizes that water accounting centres on analysis of trends in water supply, demand, accessibility and use in time and space within specified domains.

BOX 1.1
Definition of water accounting

Water accounting is the systematic study of the current status and trends in water supply, demand, accessibility and use in domains that have been specified.

Source: FAO, 2012

In a practical sense, water accounting is used as a basis for evidence-informed[6] decision-making and policy development by answering questions such as: What are the underlying causes of imbalances in water supply (quantity and quality) and demand of different water users and uses? Is the current level of consumptive water use sustainable? What opportunities exist for making water use more equitable or sustainable? Water accounting is often used as a basis for multi-scalar assessments of: 1) The efficiency or productivity of different water uses or users; and 2) The risk that attempts to increase water efficiency or productivity result in negative externalities, i.e. someone's gain in water productivity will result in someone else's reduced access to unpolluted water.

A critical aspect of water accounting is that it considers and assesses both the supply and the demand sides of water supply systems. From the perspective of water accounting, water supply and demand can be characterised as follows:

Supply side:

- The availability of rainfall, surface water, groundwater and unconventional water resources (e.g. treated waste waters) in space and time.
- Capacity, condition and O&M procedures of water supply, storage and treatment infrastructure.

Demand side:

- Different users demands for water in space and time, and the extent to which these demands are satisfied.
- Patterns of consumptive or non-consumptive water use in space and time.
- Water service levels that are experienced by different users in space and time and the benefits

BOX 1.2
Water accounting is the foundation of sound water management decisions

A major strength of water accounting is that it can be used to:

Consolidate, assess and interpret information and evidence from a wide-range of different sources.

Develop an information base for specified domains that is shared and accepted by key stakeholders.

Support cycles of learning, stakeholder dialogue and evidence-informed decision-making.

Source: Foster *et al.*, 2009

[5] In this context a sink refers to a process, phase or mechanism from which water cannot be recovered and/or recycled at a reasonable cost (e.g. water that evaporates into the atmosphere, flows into the sea or percolates into a highly saline aquifer).

[6] In most cases, it is rarely sufficient to provide only the available evidence. Evidence has to be explained; presented in ways that are easy to understand and assimilated or translated into recommendations.

they derive in monetary and non-monetary terms such as improved health and well-being.

Water accounting has developed from three distinct perspectives namely hydrology, irrigation or civil engineering and monitoring and evaluation (After Perry *et al*., 2009). All three perspectives have merit:

- The **hydrological perspective** is based firmly on an understanding of the physical processes that govern volumes and rates of water flows, fluxes and stocks in different landscapes and/or under different agro-climatic conditions or management regimes.
- The **engineering perspective** focuses primarily on the design, construction and operation of storage structures, bulk transfer schemes, well fields, irrigation and drainage schemes, municipal water-supply systems and water treatment plants. Or, put another way, the focus is on managing stocks of water (in time and space) and the transfer of water through pipelines and canal systems from sources to where it is needed .
- The **monitoring and evaluation perspective** focuses on using water accounting to support or underpin management decisions or as a means to learn lessons or gain incremental improvements in policies and practices on both the supply and demand sides of water supply and water services delivery systems.

Methods and tools used in water accounting are well-known to hydrologists and engineers such as mapping and spatial analysis, water balance analysis, water quality analysis, trend analysis, modelling of water flows, fluxes and stocks and demand forecasting. Information collected during water accounting is typically varied and addresses a range of biophysical issues. Similarly, outputs are equally diverse in their formats and their target uses and audiences.

1.3.2 Why does water accounting matter?

Water accounting matters because, without reliable information, debate is uninformed and stakeholders have no basis for challenging factually incorrect or biased positions. Similarly, effective planning is near impossible if stakeholders are working with their own differing information bases. Yet, such a situation is very common. For example, government line departments, when attempting to align plans, rarely have access to a common information base. Similarly, local-level water users may have a very different perception of their levels of water services as compared to organizations that are responsible for delivering these services. A key output of water accounting is, therefore, a common information base that is acceptable to all the key stakeholders involved in planning or other decision-making processes.

Water accounting also matters because often disconnects exist between hydrological knowledge based on scientific evidence, and popular understanding of hydrology based on beliefs, folklore and hearsay. Specifically, there is often a widespread misunderstanding regarding the potential impacts of changes in land use and land management systems on the hydrology of catchments (and aquifers). Many of these disparities, but certainly not all, relate to the impacts of forests and forest management on hydrology. Box 1.4 summarises the state of scientific

BOX 1.3

The water accounting challenge

Water is a renewable resource but patterns of water availability and accessibility:

vary in space and time;

are influenced by both biophysical and societal factors.

Source: FAO, 2012

BOX 1.4
Influence of forests on hydrology

State of knowledge as summarised by a task force organized by the International Union of Forest Research Organizations (IUFRO):

Water Use by Forests: *Water use by forests is influenced by climate, forest and soil type, and other factors. In general, forests use more water than shorter types of vegetation because of higher evaporation, and less surface runoff and groundwater recharge occurs. Forest design and management practices can have a marked impact on forest water use through the mix of tree species and ages, forest structure and roughness, and the amount of felled and open ground.*

Flood Flows: *Forests can mitigate small and local floods but do not appear to impact either extreme flood events or those at a large catchment scale. One possible exception is the ability of floodplain forest to reduce downstream flooding due to hydraulic roughness acting to slow down and desynchronize flood flows.*

Erosion: *Forests protect soils and reduce erosion rates and sediment delivery to rivers. Forestry operations such as cultivation, drainage, road construction, and timber harvesting may increase sediment losses but the implementation of best management practices can control this risk. Forest creation on erosion-prone soils and run-off pathways can reduce and intercept sediment*

Source: IUFRO, 2007

knowledge concerning some aspects of the impacts of forests on hydrology that are contentious in many parts of the world despite advances in scientific understanding.

Water accounting can play a central role in identifying hydrological beliefs that are, in reality, myths. It is important, however, to recognize that while facts and evidence may be important, they do not always change opinions. Many beliefs are deep-seated and holders of these beliefs have a tendency to reject any facts or evidence that challenges or is inconsistent with these beliefs. This issue is discussed in more detail in Section 6.

1.3.3 Water accounting concepts and terminology

The terms water accounting and water auditing have been in regular use for more than two decades often inter-changeably. Definitions have been proposed and used but consensus on the definition of these terms has yet to emerge. In fact, one of the recommendations of the FAO's Expert Consultation on coping with water scarcity in 2011 was that the FAO should develop and attempt to popularise definitions of water accounting and auditing. This recommendation prompted the definitions that are proposed and are used in this sourcebook.

Terminology used during the practical application of water accounting and auditing can be confusing for reasons that include:

- By definition, water accounting and auditing involves specialists from various disciplines who often have different definitions for the same terms. For example, economists and non-economists are accustomed to using different definitions of the term 'demand'. In economic terms 'demand' is an expression of a willingness to pay for goods and services. Whereas non-economists often understand 'demand' for water to be the same as needs or requirements for water.

BOX 1.5

Importance of hydrological and hydrogeological processes and interactions

Inter-linkages between rainfall, surface water, groundwater, soil moisture and rates or processes of evaporation from different land uses are of critical importance, and are not fully reflected in many national water management plans. Groundwater and surface water are ultimately part of the same resource, and cannot be regarded as alternative sources. Attempts to increase the efficiency of water use in a specific domain without a clear understanding of the impact on systemic water balances may lead to unintended and undesirable results either locally or downstream

Source: FAO, 2012

- Many definitions are hotly contested. Political scientists tend to define governance in terms of the exercise of political, economic and administrative authority (i.e. power) in the management of a country's affairs, whereas others define governance in terms of institutional structures and legislation (e.g. UN-WATER, 2013). To complicate matters further, the way 'governance' is defined and described is often determined by political leaning. Hence, neo-liberals define bad governance in terms of inadequate markets and excessive government. Others define bad governance from the perspective of democratic or administrative deficits or gaps (e.g. OECD, 2012).
- Some terms in everyday use vary with perspective. For example, from a farmer's perspective, drainage and deep percolation is often referred to as a 'loss'. However, from the perspective of other water users in the same locale, this 'loss' may actually be a vital source of groundwater or runoff. This is important because, in some contexts if farmers reduce 'losses' with a view to 'saving' water, they may reduce the water available to other users (e.g. van Halsema and Vincent, 2012).
- Terms and definitions change over time as new concepts are developed and become fashionable or as old concepts fail to live up to expectations and are quietly discarded or replaced.
- Different governments or international organizations have their preferred terminologies and glossaries.

Confusion over terminology is further exacerbated when a mix of languages is involved and the meanings of terms are changed or lost in translation. The practical solution to this, and other terminological challenges, is to prepare and share a glossary of current and historic terms as an integral part of water accounting and auditing. As important, attention should be given to adopting and using terminology and definitions that are familiar to stakeholders involved in the water accounting and auditing processes.

A glossary has been prepared and appended to this version of this document. It is recognized, however, that this glossary will need to be updated in future versions.

1.3.4 What are the objectives of water accounting?

Water accounting provides a sound scientific basis for evidence-informed strategy development, operational decision-making and targeted communication or awareness-raising programmes (FAO, 2012). The typical objectives of water accounting for a specified domain include:

- Within prevailing constraints (e.g. human and financial resources, access to information and so on), to produce the most rigorous quantitative and qualitative description of the current status and trends in water supply, demand, accessibility and use.
- Linked to the above, to develop a sound understanding of the predominant biophysical mechanisms, processes and pathways that determine flows, fluxes and stocks of water and the associated transport of contaminants and pollutants in rivers, soils, and aquifers.
- To identify the underlying biophysical causes of problems relating to imbalances in water supply and demand.
- To assess the probability of risks and scales of extreme events (e.g. floods, droughts, pollution with natural or anthropogenic contaminants) in the specified domain.
- To assess the resilience or vulnerability of society and the environment to extreme events and more gradual biophysical changes linked to, for example, water scarcity, climate change and food security.
- To identify and, wherever necessary, resolve fundamental differences of opinion or understanding between stakeholders and/or specialists related to: 1) The severity or underlying causes of water-related problems; and 2) The potential utility of different strategies for tackling these problems.
- Linked to the above, to establish a shared information base that contains, uncontested information[7].
- To use multi-scalar analysis to identify consumptive and non-consumptive water uses at different scales and the potential for using recycling or return flows to increase the net beneficial use of water and reduce risk of pollution.
- To identify the scale, severity and nature of inter-sectoral or upstream or downstream conflicts over the allocation (or appropriation) of water resources.
- To assess whether or not existing water policies and practices are working well and whether they are resulting in unintended consequences (or externalities) locally or downstream.
- To identify and assess the scale, severity, locations and causes of inequities in access to water and/or inability to exercise formal or informal rights to water.

BOX 1.6

Bayesian approaches to water accounting and auditing

Bayesian approaches to accumulating and using evidence are well suited to water accounting and auditing. These approaches start with a set of beliefs or assumptions regarding the water-related status of a specified domain and the probability that priority challenges or issues have certain root causes. When new information and evidence is accumulated, a priori beliefs and assumptions are tested and, if necessary changed. Or put another way, beliefs, assumptions and understanding are constantly updated as additional, good-quality information and evidence becomes available.

[7] The reality is that it may be impossible to achieve a situation where all the information in a shared database is uncontested. As a consequence, a more practical goal may be to work continuously towards this aspirational goal.

- To use state-of-the art modelling (including Bayesian Networks – see Box 1.6), scenario building and similar techniques to test hypotheses and assess the utility of existing or improved policies and practices;

1.3.5 Water accounting approaches

There are good arguments for and against taking a standardised approach to water accounting[8] or the more adaptable flexible approach described in this sourcebook. In short, a standardised approach better supports inter-country comparisons, while a more adaptable flexible approach makes it possible to align the type of water accounting to the needs and priorities of key stakeholders, to specific problems or to specific biophysical and societal contexts.

With regard to the water accounting approach described in this sourcebook, various choices need to be made when planning water accounting and auditing programmes. Often these choices are influenced by factors such as the availability of funds and time; the size of the specified domain; the accessibility of secondary information; and the availability and costs of specialists.

One important choice is between rapid or comprehensive water accounting. As their names imply, these are two extremes of a continuum. Experience has shown that it is often best to carry out water accounting procedures in cycles of increasing focus and complexity starting with an initial rapid water accounting. The aim of each cycle is to guide or inform subsequent more detailed and focused cycles of information collection and analysis that build towards more comprehensive water accounting. The typical characteristics of rapid and comprehensive water accounting are compared in Table 1.1.

A distinction also needs to be drawn between one-off water accounting approaches that, for example, are designed to support a project or a programme and water accounting that is part of an adaptive management programme that aims to achieve long-term policy objectives. In the former case, it is likely that the institutional arrangements for implementing water accounting will be temporary and most likely outside government.

TABLE 1.1
Comparison of rapid and comprehensive approaches to water accounting

Rapid	Comprehensive
Initial identification of priority problems or issues relating to trends in water supply, demand and access within a specified domain	Aimed at developing a comprehensive water-related information base that covers all water-related water supply and issues relevant to a specified domain
Initial assessment of relatively easily accessible quality-controlled secondary data relating to trends in water supply, demand and accessibility. Primary data collection restricted to gap filling. Initial assessment of causes of problems	Comprehensive consolidation, quality control and assessment of secondary data relating to trends in water supply, demand and accessibility. Primary data to fill gaps and to give new insights into the causes of and potential solutions to problems
Stakeholder dialogue aimed at identifying priority issues or problems. Preliminary identification of possible causes of and solutions to problems	Establishment of a multi-stakeholder platform to ensure that stakeholders are actively involved in identifying root causes of and solutions to individual and/or combinations of all problems

[8] The System of Environmental-Economic Accounting for Water (SEEAW) is a standardised approach to water accounting that is popular and well documented. SEEAW is also reviewed in FAO (2012) and Perry (2012).

While in the latter cases, it is possible that water accounting will be adopted and used by a government department, agency or authority that already has an inter-sectoral remit (e.g. a national or river basin planning department or a national water regulatory authority).

1.4 WATER AUDITING

1.4.1 What is water auditing?

In this sourcebook, water auditing is defined as a process that places the findings, outputs and recommendations of water accounting into a broader framework comprising governance, institutions, public and private expenditure, legislation, services delivery and the wider political economy of specified domains (see Box 1.7). As such, the focus of water auditing is on assessing and understanding the broader societal context of water management, water supply or water services delivery (see Box 1.8).

Similar to water accounting, water auditing can take many different forms ranging from a relatively rapid one-off activity designed to achieve a specific purpose through to a long-term Monitoring & Evaluation programme that aims to achieve, for example, equitable and efficient water services delivery for a wide-range of uses such as irrigation; domestic water, sanitation and hygiene (WASH); power generation; inland fisheries; environmental flows, navigation and so on. Information collected during water auditing is typically varied and addresses diverse range of societal issues. Outputs are equally varied in their form, formats, target audiences and uses.

BOX 1.7
Definition of water auditing

Water auditing goes one step further than water accounting by placing trends in water supply, demand, accessibility and use in the broader context of governance, institutions, public and private expenditure, legislation and the wider political economy of water of specified domains.

Source: FAO, 2012

BOX 1.8
Assessing the context

Governance interventions are not introduced in a vacuum. They are built on some foundation of existing capacity – even if that capacity is low. By asking the question 'What is there to build on?' interventions that are appropriate for specific situations can be more easily identified. Two analytical frameworks are helpful in this regard: one that focuses on assessing the strengths and weaknesses of states and one that provides insight into the opportunities for change that might exist in different biophysical and societal contexts.

Source: Grindle, 2007

Experience has shown that to be effective in terms of producing high quality outputs that are owned and used by key stakeholders, a water auditing programme should: 1) Be based on active stakeholder engagement; 2) Give specific attention to managing information; and 3) Be linked to a communication strategy that recognizes the intrinsic challenges of influencing political and public opinion.

1.4.2 Why does water auditing matter?

Over the last decade or so, statements, such as ‘the world water crisis is mainly a crisis of governance’ (GWP, 2000), have been repeated many times by politicians, academics, journalists, activists and many others. This statement is underpinned by the widely-held belief that governance and political economy factors play a powerful role not only in a country’s development path, but also in shaping policies and determining the way in which these policies are implemented (World Bank, 2009; 2013). Therefore, there is a wide consensus that governance assessment and political economy analysis are essential steps in programmes that, for example, aim to achieve and maintain acceptable levels of water services.

Water auditing matters also if key stakeholders are ‘to do better[9]’ by, for example:

- Learning from the past and, more specifically, consolidating and making good use of biophysical and societal evidence that gives an indication that specific policies and practices are or are not working.
- Making choices that are informed by evidence rather than intuition or guesswork (see Box 1.9).
- Developing new policies and practices or adapting existing policies and practices so that they, for example, take better account of imbalances in water supply and demand.
- Communicating information in ways that increase the probability that it will be owned, accepted, valued and used.

1.4.3 Water auditing concepts and terminology

Increased interest in the governance and political economy of water in recent years is linked in part to the perceived failure of technological advances to translate into

BOX 1.9

Opportunities for problem-driven learning

Stakeholder engagement in water auditing creates opportunities for stakeholders to be actively involved in:

Identification of problems and their underlying causes.

An incremental process of adaptation and innovation that leads to relevant solutions that will probably be politically acceptable and practically possible.

Source: Andrews, 2013

[9] ‘To do better’, it is important for stakeholders to believe that there may be scope for improvement either in policies and practices as formulated or the ways in which these are interpreted and implemented.

improvements on the ground (Green, 2011). This has prompted international agencies, in particular, to develop and use different approaches to governance assessment and political economy analysis. While this diversity provides potential users with plenty of choice, the trade-off is that: 1) They may have the problem of selecting an approach that best meets their needs; and 2) They are often confronted by different definitions of the same term (see Box 1.10).

BOX 1.10

Definitions of power

Definitions of political power include:

> *"The capacity to intervene in a given set of events so as in some way to alter them" (Anthony Giddens, 1985).*
>
> *"The probability that one actor within a social relationship will be in a position to carry out his own will despite resistance" (Max Weber, 1922).*
>
> *"….corresponds to the human ability not just to act but to act in concert. Power is never the property of an individual: it belongs to a group and remains in existence only as long as the group keeps together" (Arendt 1970 cited in Haugaard, 2002).*

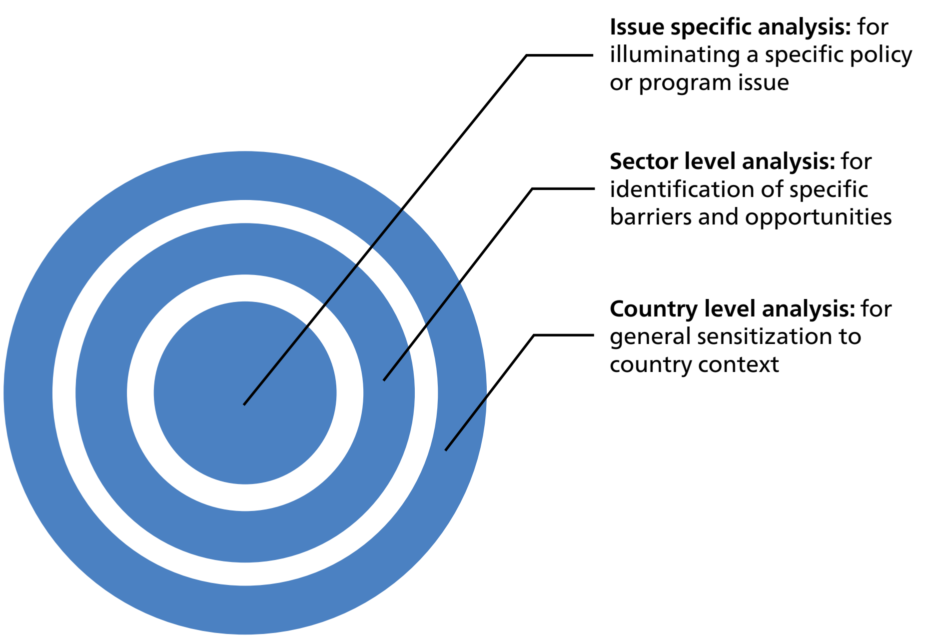
Source: Green, 2011

A common feature of most water auditing concepts and terminology is the link to politics and the ways in which power and authority are exercised (see Annex 1 for the Glossary). Water auditing concepts and terminology refer also to (After DFID, 2007):

- The ways in which people mediate their differences; make decisions; and enact policies that affect public life and economic and social development.
- Relationships between citizens and the state and, more specifically, how these relationships are influenced by institutions and the way in which formal rules (i.e. statutory laws and regulations) and informal rules (shaped by tradition and culture) affect the way people relate to each other.
- The ways power is held, used and projected in different contexts and, as important, how those who exercise power can be held to account if they abuse or misuse this power.
- How a society or a political system makes choices about the way in which people live together such as social norms, how competing interests are mediated and how available resources are allocated.

Given the link of water auditing concepts and terminology to politics, it is not surprising that many of the definitions listed are contested because they either promote or, in some cases, fail to promote a particular ideological viewpoint. For example, neo-liberals like to define poor governance very specifically in terms of inadequate markets and excessive government. Hence for neo-liberals, many problems can be solved by: 1) Removing constraints to the operation of a market-based economy; and 2) Minimising the role of government. Conversely, others define the quality of governance at different institutional levels from the perspective of a democratic deficit. Thereby, defining overall governance in terms of a shortfall in various indicators of good governance such as, for example, transparency, accountability, representativeness, responsiveness, efficiency and so on (Green, 2011).

FIGURE 1.1
Levels of governance assessment and political economy analysis



Source: Harris et al., 2011

From the viewpoint of water auditing, it is only necessary to recognize that definitions listed are contested and that, for most practical and apolitical purposes, it is better to adopt definitions that are descriptive and do not prescribe what is or is not needed. This is often easier said than done, because different countries and international agencies have their own preferred concepts and terminology concerning water auditing that are anything but apolitical.

1.4.4 What are the objectives of water auditing?

Objectives of water auditing include:

- Identifying the underlying societal causes and feedback mechanisms that lead to, for example, the unsustainable use of water resources; lack of, or poorly maintained, infrastructure; and the inadequate, unsustainable, inequitable or inefficient delivery of water services.
- Identifying, adapting or developing solutions to priority water-related problems that are politically, socially and culturally acceptable; taking account of biophysical limitations; and recognizing wider policy imperatives (e.g. poverty reduction, protection of environmental flows, management of risks linked to climate change).
- Providing a coherent framework for assessing the wide-range of societal factors that influence trends in water supply, demand and access and the delivery of sustainable, equitable and cost efficient delivery of water services.
- Gaining a good understanding of how water-related decisions are made in specified domains and, more specifically, how deals are negotiated informally and formally at different institutional levels.
- Assessing the effectiveness and utility of statutory and customary laws and systems of enforcing these laws in terms of, for example, ensuring that the

BOX 1.11
The multi-faceted challenge of improving governance

Often reforms are needed to improve governance that touches virtually all aspects of the public sector – from institutions that set the rules of the game for economic and political interaction, to decision-making structures that determine priorities among public problems and allocate resources to respond to them, to organizations that manage administrative systems and deliver goods and services to citizens, to human resources that staff government bureaucracies, to the interface of officials and citizens in political and bureaucratic arenas. Not surprisingly, advocating improved governance raises many questions about what needs to be done, when it needs to be done, and how it needs to be done.

Source: Grindle, 2004

demands of different water users and uses are assured and protected and whether or not possible externalities (e.g. in relation to upstream or downstream issues) are negated or minimised.

- Using a range of well-proven investigative and diagnostic methods and tools to gain insights into the reasons why carefully designed water sector reform programmes often fail to deliver desired outcomes. Similarly, to gain insights into the societal (and biophysical) reasons as to why it can be relatively simple to upscale localised success stories in some cases but very difficult in others.
- Using expenditure reviews, life-cycle cost assessment, cost curve analysis, input tracking and other tools to track both public and private expenditure value-for-money relative to various biophysical, societal and environmental indicators.

1.4.5 Water auditing approaches

This sourcebook recommends three different approaches to water auditing, namely:

- Governance assessment[10]
- Political economy analysis[11]
- A combination of governance assessment and political economy analysis[12]

The attributes of these three approaches to water auditing are compared in Table 1.2. However, a crucial first step is to identify the needs, priorities and the institutional levels at which water auditing will be of most value to key stakeholders. Only then should a decision be made concerning the most appropriate approach to water auditing. Consideration should also be given to the potential synergies between water accounting and water auditing. Mutual support and integration of interdisciplinary biophysical and societal analysis will be easier and more productive if the same or similar spatial and temporal scales and granularities are used when collecting, processing and analysing information and making recommendations.

10 For an example of guidelines for governance assessment see: http://www.undp.org/content/rbas/en/home/presscenter/events/2012/November/regional_governance_week/_jcr_content/centerparsys/download_8/file.res/Planning%20a%20governance%20assessment.pdf

11 For examples of political economy analysis guidelines see: http://www.gsdrc.org/docs/open/PO58.pdf or http://capacity4dev.ec.europa.eu/political-economy/document/how-notes-political-economy-assessments-sector-and-project-levels

12 For an example of combined approach guidelines see: http://siteresources.worldbank.org/EXTPUBLICSECTORANDGOVERNANCE/Resources/PGPEbook121509.pdf

At the core of both political economy analysis and governance assessment is the analysis of power: how it is used and on whose behalf institutions function at different levels in a particular country; how the relations between rulers and organized groups in society or citizens operate; and how sectors are governed (European Union, 2008).

While the aims of political economy analysis and a governance assessment are similar, there are fundamental differences between the approaches taken (Harris *et al*., 2011). As its starting point political economy analysis takes the societal context as it exists within a specified domain, and then focuses on identifying underlying causes and workable solutions to problems as and when they are identified. In contrast, most governance assessments aim to measure the performance or level of governance in a specified domain against certain pre-established criteria and/or indicators of good governance. In other words, governance assessment often takes the form of a gap analysis that starts with a vision of what governance should look like[13] and compares actual performance

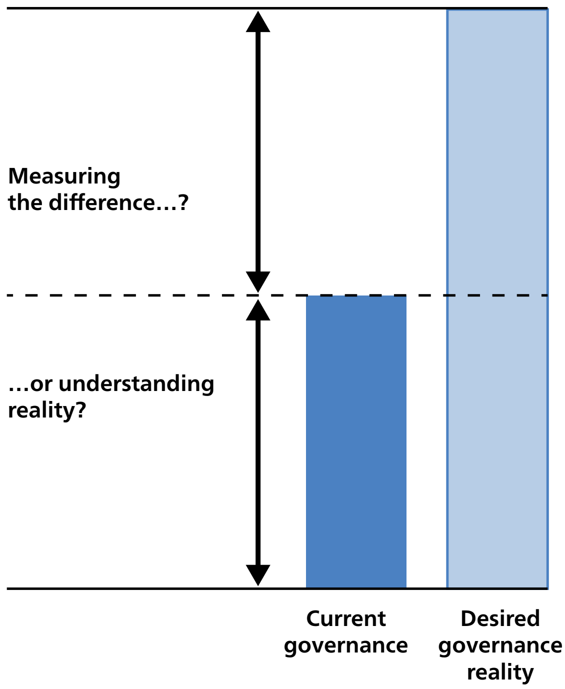
TABLE 1.2
Comparison of key attributes of governance assessment, political economy analysis and a combination of governance assessment and political economy analysis

Attributes	Governance/assessment	Political/economy/analysis	Combined/governance/ assessment/and/ political/economy/analysis
Adaptable and flexible	All three approaches can be adapted to meet specific needs or a specific context		
Guidelines and case studies available on the web	No major differences		
Problem-focused	More likely to be prescriptive	Designed to identify and analyse problems and/or opportunities	Can be both prescriptive and problem-focused
Interdisciplinary/holistic	Focus mainly on governance principles and indicators	More wide-ranging. Can also include expenditure review, accountability assessment, reviews of legislative frameworks, approaches to managing demand	
Multilevel analysis	More likely to be used at one level (i.e. the macro or national level)	Designed to study governance and the political economy of a specified domain at different levels	
Stakeholder sensitivities	Less threatening especially if indicators are modified following stakeholder dialogue	Maybe perceived as more intrusive and threatening	Can start with a governance assessment and progress towards political economy analysis
Specialist inputs	Relatively less required	Relatively more required	
Presentation on maps along with biophysical info	Relatively easier especially if geo-referenced ordinal scoring is used	Relatively more difficult	Relatively easier especially if geo-referenced ordinal scoring is used
Strategic governance objective	Emphasis is on achievement of "good governance"	Emphasis is on achievement of "good enough governance"	
Operational value to strategy development, planning and M&E	Most useful for comparative analysis or monitoring of governance	Most useful for evaluating the causes of problems and identifying solutions to these problems	Can be useful for monitoring, identifying the cause of problems and evaluating opportunities
Usefulness as a "partner" to water accounting	Most useful as a partner to rapid water accounting	Most useful as a partner to comprehensive water accounting	If sufficient resources are available, the best partner
Time and expenditure	Stakeholder/sensitivities	Stakeholder/sensitivities	Stakeholder/sensitivities
Specialist/inputs	Relatively less required	Relatively more required	Likely to be the most expensive and time consuming option

[13] In many cases 'good governance' is perceived as an idealised version of the governance systems of developed Western countries (Harris *et al*., 2011).

to this vision. Thereby identifying what is lacking against a number of indicators (e.g. accountability, responsiveness, efficiency, equity and so on). While this approach to governance assessment has its merits (see Table 1.2), it has been criticised for being prescriptive and normative. Governance assessments have also been criticised for highlighting under-achievement and for not generating sufficient information to explain the reasons why governance in a country, in a sector or in relation to a specific issue might be rated as having relatively low (or high) scores against some or all the governance indicators.

FIGURE 1.2
Selecting an appropriate 'lens' for examining governance



Source: EU, 2008

Figure 1.2 provides another way of looking at the differences between governance assessments, political economy analysis and some combination of the two. In short, governance assessments focus on measuring the difference between the current level of governance and a desired normative level of governance. In contrast, the focus of political economy analysis is on understanding the reasons for a certain level of governance in relation to a nation state, a sector or an issue. The combined approach, as the name suggests, attempts to: 1) Measure or quantify the difference between actual governance and a vision of what the governance could or should be; and 2) Identify the reasons why governance indicators in a specified domain might be high or low.

Interest in political economy analysis and, in some cases, combined governance assessment and political economy analysis has been driven by a strong desire to better understand sector reform processes (see Box 1.12). As such, it is argued also that political economy analysis is an approach or methodology that can better:

- Help sector specialists identify appropriate policy responses in a given context, designing and implementing approaches that 'best fit' existing institutional structures and incentives, rather than imposing an external model of best practice (Kooy and Harris, 2012);
- Support approaches to sector reform processes that aim to be pragmatic, incremental and opportunistic in terms of governance[14] and institutional development[15].

The differences between governance assessment and political economy analysis that have been highlighted in this section should not be seen as a recommendation that governance assessment, political economy analysis or the combined approach are

[14] Grindle (2007) argues the case for adopting the 'good enough governance' concept for selecting or supporting fewer but more useful and more feasible interventions.

[15] Merrey and Cook (2012) argue that rather than attempting to impose new institutional arrangements, the focus should be on promoting and facilitating innovation at local levels, while at the macro-level the focus should be on managing change and building institutional capacity (Merrey and Cook, 2012).

BOX 1.12
Typical sector reform questions

Typical questions development practitioners ask when trying to better understand and support sector reforms include:

- Why do sector reforms sometimes slow down, stop or reverse despite technically sound policy content?
- What are the political, economic and social forces that drive or block policy change in specific sectors?
- Which opportunities and incentives as well as which constraints and disincentives are reformers facing?
- Why is the 'political will' for sector reforms sometimes strong and sometimes weak?
- And how could development partners best create, strengthen or sustain this political will for sector reforms?

Source: Edelman, 2009

always the better option. Rather, the main point is that these approaches serve different purposes, have different attributes and typically require different inputs of skill, time and expenditure.

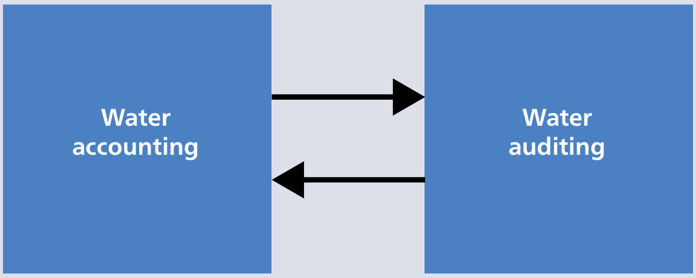
1.5 COMBINING WATER ACCOUNTING AND AUDITING

1.5.1 Why combining water accounting and auditing?

Although water accounting can be, and often is, carried out in isolation from water auditing, the view taken in this guide is that water accounting and auditing are best designed and implemented as mutually-supportive processes (see Box 1.13 and Box 1.14). There are practical reasons for combined water accounting and auditing. For example, there is higher probability of identifying the underlying causes of water-related problems and viable opportunities for addressing problems. A more fundamental reason, however, is that water accounting is more likely to prompt change if it is carried out in conjunction with water auditing. A lesson from water sector reform programmes is that changes often fail or take decades to achieve their goals. In part because institutional reform, to be legitimate and have broad political support, has to emerge through a political process. Opportunities for overcoming resistance to change and make step-change improvements in governance at different institutional levels are often transitory. A significant attribute of water auditing is it can play a role in identifying or predicting good opportunities or windows for promoting change such as becoming part of the development of theories of change[16]. Finally, water auditing without water accounting is even more risky than water accounting without water auditing because it can result in change being promoted that, for biophysical reasons, has little chance of delivering benefits and, in some circumstances, may even make things worse for some water users or uses.

[16] For information on developing and updating theories of change see Valters (2015).

BOX 1.13
Water accounting and auditing are mutually supportive



Water accounting supports water auditing by providing insights, understanding and information, for example:

- Physical availability of water stocks and flows in time and space;
- Balance between water supply, demand and access;
- Physical capacity and condition of water-related infrastructure;
- Levels of water security of different users and uses;
- Frequency of droughts, floods and interruptons in the delivery of water services;
- Types of water use in time and space (e.g. consumptive and non-consumptive);
- Efficiency, productvity and profitability of different water uses and users in time and space;
- Functonality of policies and programmes aimed at regulating demand and improving supply;
- Potental tradeoffs or externalites resultng from intensificaton of water use;
- Opportunites for making better use of water from "source to sink" and along the value chain;

Water auditing supports water accounting by providing insights, understanding and information on, for example;

- Stakeholder roles, responsibilites and inter-relatonships at different levels;
- Governance systems i.e. how decisions are made, where power resides and how power is mediated;
- Reasons official statistics may not reflect ground level realities;
- Political, social and environmental concerns priority issues;
- Levels of public and private expenditure e.g. on operation and maintenance;
- Functionality of formal and customary laws;
- Underlying reasons for "lack of politcal will" to promote and implement change;
- Levels of accountability and transparency.

BOX 1.14

Typical water accounting and auditing activities

Water accounting

Water accounting includes the systematic identification, assessment and analysis of the following in space and time:

- Status and future trends in water supply, demand accessibility and use;
- Underlying causes of imbalances in supply and demand;
- Levels of environmental sustainability;
- Levels of water efficiency and productivity from source to sink and along the value chain;
- Capacity, functionality and O&M of water supply, storage, treatments and drainage related infrastructure;
- Water services levels of different uses and users;
- Condition of environmental flows;
- Levels of equity and levels of competition for water;
- Functionality and effectiveness of M&E systems;
- Identification and assessment of potential externalities linked to, for example, land use change and agricultural intensification.

Water auditing

Water auditing includes the systematic identification, assessment and analysis of the following at different institutional levels:

- Systems of water governance and particularly the way in which power and authority are exercised and mediated;
- Mandates, interactions, functionality and accountability of formal and informal water-related institutions;
- Utility and effectiveness of different water services delivery models;
- Effectiveness and utility of policies relating to water and food security, poverty alleviation etc.;
- Levels of public and private capital and recurrent expenditure;
- Profitability and cost-benefits of different water uses and users;
- Laws and regulations (formal and informal and their enforcement;
- Effectives and transparency of systems water allocation and regulation;
- Wider political economy issues that often underpin sanctioned discourses and resistance to change.

1.5.2 Attributes of water accounting and auditing

Attributes of the approach to water accounting and auditing recommended in this sourcebook include these features:

- It is flexible, adaptable, inter-sectoral, multi-scalar and based on a sound up-to-date understanding of the various disciplines involved (e.g. hydrology, civil and irrigation engineering, political science, economics, social sciences).
- It stresses the importance of effective information management and probabilistic analysis of both hard and soft information and evidence[17].
- It is based on a process of active stakeholder engagement, concerted action and cycles of social and institutional learning.
- It recognizes the importance of developing and implementing a communication strategy as an integral part of a water accounting and auditing process.

Another attribute of the recommended approach is that it has evolved over twenty years or more from placing emphasis on biophysical and infrastructural aspects (e.g. estimation of water balance components at different scales for different water uses in space and time; capacity, functionality and management of water supply and treatment infrastructure) to being more interdisciplinary and inter-sectoral. This transition has been driven in part by the realisation that, as water scarcity increases, engineering or technical solutions on their own are less likely to solve water-related problems. Or put another way, political, institutional, social, economic, cultural and other factors become increasingly important as competition for limited water resources increases.

1.5.3 Overall approach to water accounting and auditing

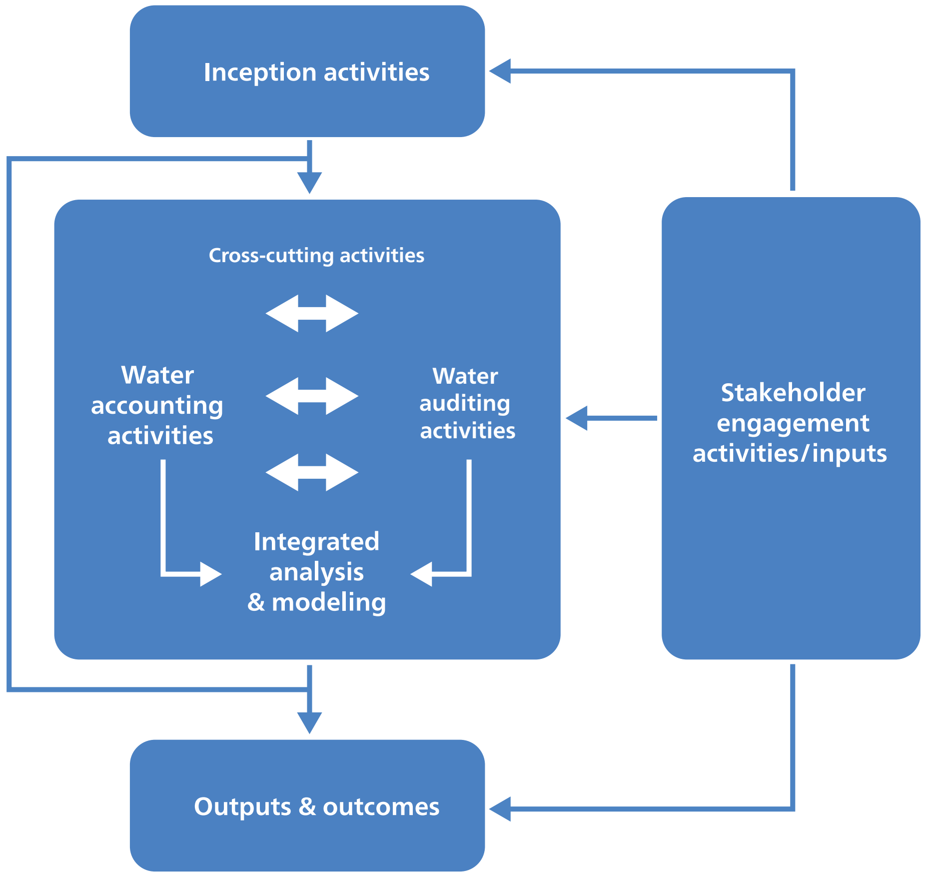
The overall approach to water accounting and auditing recommended in this sourcebook is relatively simple (see Figure 1.3) and is comprised of:

- **Inception activities** are required to start water accounting and auditing processes. Some are one-off activities (see Section 3). Others may need to be repeated or continued during the water accounting processes.
- **Stakeholder engagement activities or inputs** involve the recommended active engagement with stakeholders throughout water and accounting processes. In other words, there are almost always significant benefits to be gained when stakeholders are actively engaged in inception activities; in cycles of water accounting and auditing; and in the formulation and delivery of desired outputs and outcomes.
- **Cycles of water accounting and auditing** are typically water accounting and auditing, which is implemented in a number of iterative cycles. Starting with relatively rapid or coarse assessments or analysis and, with each cycle, refining the analysis and increasing confidence in outputs. It is usually best to plan and implement water accounting and auditing as mutually supportive parallel processes, rather than processes that are carried out in series. This requires careful planning, appropriate sequencing of activities and a willingness of all involved to share findings and participate in multi-disciplinary dialogue.

  Within water accounting and auditing processes, some activities are focused primarily on water accounting (e.g. targeted biophysical assessments or water balance analysis) or water auditing (e.g. governance assessments or political economy analysis). Other activities are more crosscutting and, as such, require

[17] **Hard information** is scientific knowledge and technical or biophysical information that is often quantitative in nature. **Soft information** is societal information, expert opinion or perceptions that are usually qualitative in nature

FIGURE 1.3
Overall approach to water accounting and auditing



multi-disciplinary dialogue and coordination (e.g. information acquisition and/or identification of the underlying causes of water scarcity). There are also activities that concentrate on more detailed, and often more complex, integrated analysis and modelling. The aim is to build on the crosscutting activities by extracting additional insights into the biophysical and societal causes of problems and potential opportunities for addressing these problems.

- **Outputs and outcomes** are typically outputs and outcomes that have been identified and agreed upon during inception activities. It is always likely, however, that these will have been discussed with stakeholders and refined as more information becomes available about the domains of interest. If positive outcomes are to be achieved, it is important that outputs be owned by and the confidence of key stakeholders has been gained. This is best achieved by communication of provisional findings and regular formal and informal discussions with key stakeholders.

1.5.4 Some characteristics of the approach

The recommended approach to water accounting and auditing includes:

Effective planning, management and leadership are crucial to ensuring that:

1) The type and level of integration, in a given context, are appropriate (see Box 1.15);

2) Various components and activities are properly sequenced and coordinated;

3) Synergies are achieved between the various components and processes;

4) Stakeholders are actively engaged from inception through to delivery of outputs and outcomes;

5) Effective storage and sharing of information; and

6) Effective sequencing and coordination of the various components.

Iterative and adaptive cycles of work: Typically water accounting and auditing are planned and implemented in a series of iterative cycles that identify and focus increasingly on priority issues or opportunities (see Figure 1.4).

In the first cycle, the approach is: 1) Relatively rapid; 2) Relatively limited in terms of inter-disciplinary scales analysis of biophysical and societal information, and relatively coarse and limited in terms of the temporal and spatial scales addressed. However, with each cycle, information acquisition and analysis is better targeted, more detailed, more multi-scalar and more interdisciplinary. Table 1.3 summarises some typical benefits that can accrue when stakeholders are actively engaged in a cyclical learning process (After Pahl-Wostl, 2009; Moriarty *et al*., 2010). References to uncertainty are included in this table because the attitude of stakeholders towards uncertainty often has a bearing on their acceptance of water accounting and auditing outputs. High levels of uncertainty can also change the inferences and conclusions that are drawn from the process of water accounting and auditing.

If water accounting is being used for Monitoring & Evaluation, it is probable that a less iterative and adaptive approach will be adopted because the information acquired may be used, say, for time series analysis or benchmarking.

- **Multi-scalar information acquisition and analysis** that: 1) Differentiates between consumptive and non-consumptive water uses (in space and time); 2) Assesses the extent to which non-consumptive water can and is recovered by different water users (in space and time); and 3) Considers the validity of claims that water saving technologies are freeing up water for additional or alternative uses. Note also that the outputs from this type of analysis can also be used to obtain a robust estimate of water use efficiency and productivity (in space and time).

  Affordability and practicality: Clearly water accounting and auditing programmes should be affordable and represent good value for money to those funding or actively involved in the programmes (see Box 1.16). Clearly water accounting and auditing should be practical and doable. In both cases, affordability and

BOX 1.15
Different types of integration

Different types of integration relevant to water accounting and auditing include:

- **Multi-disciplinary integration:** e.g. scenario building, analysis and modelling that make use of biophysical and societal information.
- **Multi-scalar integration:** e.g. identification and quantification of externalities.
- **Integration along value or supply chains:** e.g. mapping consumptive and non-consumptive water uses from the ‘field to the fork’.

FIGURE 1.4
Cyclical water accounting and auditing

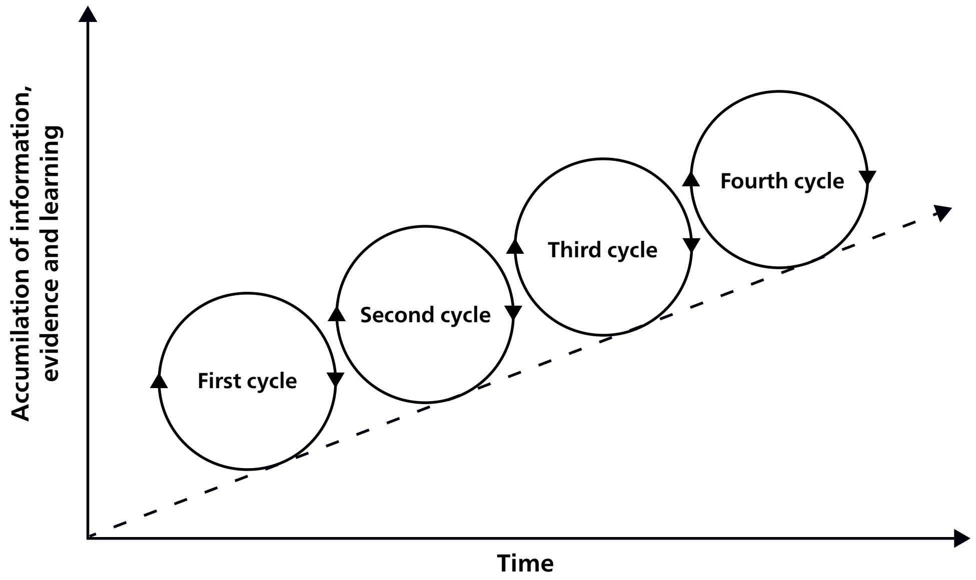


TABLE 1.3
Potential benefits of using cyclical learning-processes as a central part of water accounting and auditing

Attributes	After one cycle	After several cycles (i.e. after 2 or 3 cycles)	After multiple cycles (i.e. after 4 or more cycles)
Typical behaviour and attitudes of members of a stakeholder platform	Stakeholders continue to work and act within their own networks. Limited trust in the water accounting and auditing process	Stakeholders start seeking advice/opinions from outside established networks. Willingness to discuss politically-sensitive sectoral problems and issues	Significant changes in network boundaries and connections. Willingness to discuss and act on politically-sensitive multi-sectoral problems and issues.
Specialists (working in an interdisciplinary team)	Specialists gain a better understanding of the terminology and methodologies used by other disciplines	Much improved sharing of ideas and joint planning of activities that maximise inter-disciplinary synergies	Specialists are comfortable debating findings across a wide range of different disciplines
Water accounting and auditing recommendations	Low level of confidence in findings. Focus on getting the basics rights and a few low-risk recommendations	Increased level of confidence in findings. Focus existing policies and practices that evidence shows are working well	Relatively high-level of confidence. Focus on identifying and assessing new opportunities.
Stakeholder use and/or perception of uncertainty	Uncertainty used to justify nonaction	Indications of uncertainty being accepted and perceived as an opportunity	Uncertainty mainstreamed in negotiation or reframing processes into proposed changes to policies or practices
Impact on prevailing discourses	Discourses continue to be centred on existing paradigms. Alternatives summarily dismissed	Sanctioned discourses challenged by some individuals and groups. New ideas starting to gain traction	Significant changes occur to sanctioned discourses that are backed by powerful individual or groups
Impact on institutions	No changes to established institutions and only limited interest in reforms	Consideration given to institutional reform or restructuring	Established institutions changed progressively and news one created
Impact on governance	No changes to current system of exercising or mediating power at different levels	Consideration given to reforms but within a "good-enough governance" context	Reforms taking place incrementally with adaptations as necessary

practicality can be improved: by building on relevant existing or ongoing programmes and recruiting staff to implement the programmes that already have experience of this type of work.

BOX 1.16
Planning and budgeting

When planning water accounting and auditing programmes, it is important to recognize that the following will all influence the budget, time and other resources that may be required: 1) The level of ambition of objectives; 2) Their level of complexity; 3) The availability of good quality secondary information; 4) The need for primary information collection to ground-truth, gap-fill or update secondary information; 5) The need for awareness raising and capacity building; and, 6) The nature and types of outputs and outcomes that are needed.

1.6 TIPS AND TRICKS

- Do not try to 'account for every drop water' in specified domains or every detail related to governance and the wider political economy. Instead aim for water accounting and auditing that is 'good enough' or 'just detailed' enough to meet identified needs.
- Treat water accounting and auditing as a cyclical learning process whereby knowledge and understanding are improved incrementally with each cycle.
- An important role of water accounting and auditing is to investigate the utility, or otherwise, of accepted wisdom and folklore concerning hydrology, climatology or the underlying causes of water scarcity.
- Make sure the entire process is open and transparent in terms of: 1) The approach, methods and procedures that are used; 2) The roles and responsibilities of individuals and organizations that are involved; 3) The accountability, fairness and inclusiveness of, in particular, stakeholder engagement; and 4) Strategies adopted for making raw data, outputs, findings and recommendations publicly available.
- Think seriously about stakeholder engagement, information management, communication and other critical ancillary activities when planning and budgeting water accounting and auditing processes. In most cases, these activities should be part of the initial plan and not a series of add-ons.
- Most specialists are accustomed to working within the confines of their own areas of specialisations (i.e. their own comfort zones). As a consequence, they may take some time to adapt to and embrace water accounting and auditing's interdisciplinary, multi-scalar and multi-sectoral working environment.
- The more key stakeholders are actively engaged in water accounting and auditing the more likely they are to accept, internalise and make use of outputs, findings and recommendations.
- In most cases, it is best to plan and implement a water accounting and auditing process that builds on and supplements existing activities, practices and programmes.
- This sourcebook is not intended to be prescriptive. Instead it should be used to plan and implement water accounting and auditing processes that: 1) Are well adapted to the biophysical and societal context of the domain(s) of interest; and 2) Have the potential to deliver outputs and outcomes envisaged by key stakeholders.

2. Inception activities and stakeholder engagement

2.1 AIMS OF THIS SECTION

This section focuses on the typical activities that are needed to get water accounting and auditing programmes started and, just as important, to decide who should be involved. In some cases, getting started is relatively easy because programmes build on earlier or ongoing initiatives. In others, getting started is much more of a challenge. Whatever the case, inception activities are important because they often have a major bearing on the success or failure of the entire programme.

Many activities that start in the inception phase continue throughout a water accounting and auditing programme. While assessments and analysis during the inception period tend to be rapid, the outputs should be sufficient to make provisional decisions on matters such as specification of domains, partnerships and a provisional implementation plan.

By involving key stakeholders in the inception phase, the probability is increased that stakeholders will feel ownership of the programme, and have confidence and take pride in the outputs and outcomes.

2.2 INCEPTION ACTIVITIES

2.2.1 Preliminary selection of domains of interest

Preliminary selection of domains of interest, scales and institutional levels normally takes place at the same time as stakeholder identification and building partnerships. Typical activities include:

- **Preliminary selection of geographical location and extent:** Key stakeholders, and/or the organization that is funding the water accounting and auditing programme, usually select the geographical location and extent of the programme. In some

BOX 2.1

Selecting spatial and temporal units

Typically specifying water accounting and auditing domains of interest involves:

- **Selecting the spatial units:** These units can be: hydrological (e.g. a river basin sub-basin or an aquifer); administrative (e.g. a district); political (e.g. a constituency); a management unit (e.g. the command area of an irrigation scheme); or, some combination of all of these units;
- **Selecting the temporal units:** These units can be based on: standard units of time (e.g. hours, days, weeks, years), management units (e.g. a crop season); financial units (e.g. a financial year); political units (e.g. the term of an elected representative); or some combination of these units.

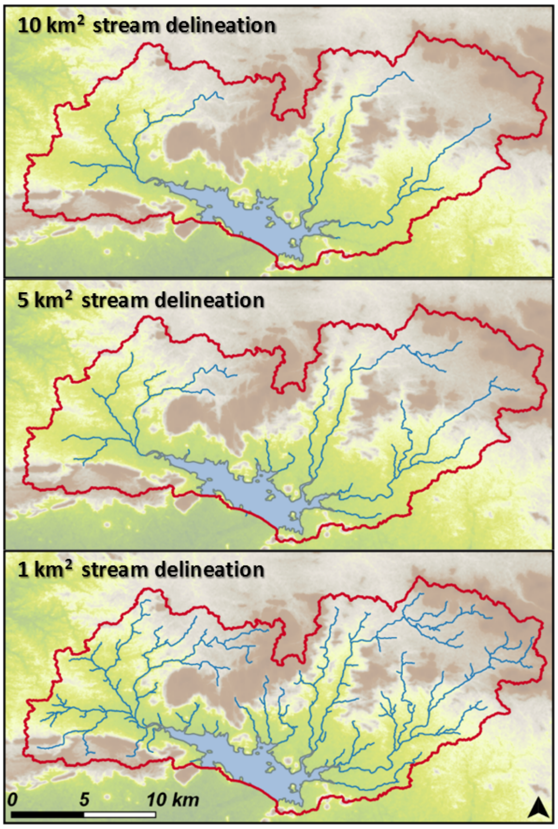
cases a prioritisation process or a needs assessment is used. In others selection of location and extent maybe be pre-determined by ongoing programmes to which the water accounting and auditing may add value.

- **Preliminary selection of biophysical and societal domains of interest:** The spatial units of both biophysical and societal domains need to be selected (see Box 2.1) along with the boundaries to be used. Selecting spatial boundaries, in particular, often needs some careful consideration (see Box 2.2). It is important to note that boundaries and spatial and temporal units are linked to scale. A common water accounting and auditing practice is initially to acquire and analyse information at a fairly coarse scale and, in subsequent cycles of accounting and auditing, to shift progressively to finer scale analysis and modelling. Figure 2.1 illustrates how progressively refining the scale of delineation of a drainage line increases the level of detail that can be observed.
- **Identifying potential sources of secondary information:** Selection of units, boundaries scales of interest should take into account the availability of reliable secondary information at the scales of interest (time and space). Aggregation and/or disaggregation of data are options but, in general, this will increase levels of uncertainty in outputs that are generated from subsequent analysis.
- **Provisional selection of institutional levels:** Another important decision relates to the number of institutional levels considered by a programme and, whether or not, to focus more on certain levels. In general, it is best to select institutional levels that align with political decision-making and the exercise of political power. Figure 2.2 shows typical institutional levels that could be selected. Note that the number and characteristics of institutional levels tends to vary from country to country.

BOX 2.2
Boundary issues

Biophysical boundaries (e.g. of a basin, aquifer or an irrigation scheme) and societal boundaries (e.g. of a country or a district) rarely overlap. From a water accounting and auditing perspective, boundary issues are fact of life that has to be acknowledged and managed. GIS software, in particular, can be used to manage, reconcile and resolve many spatial boundary issues.

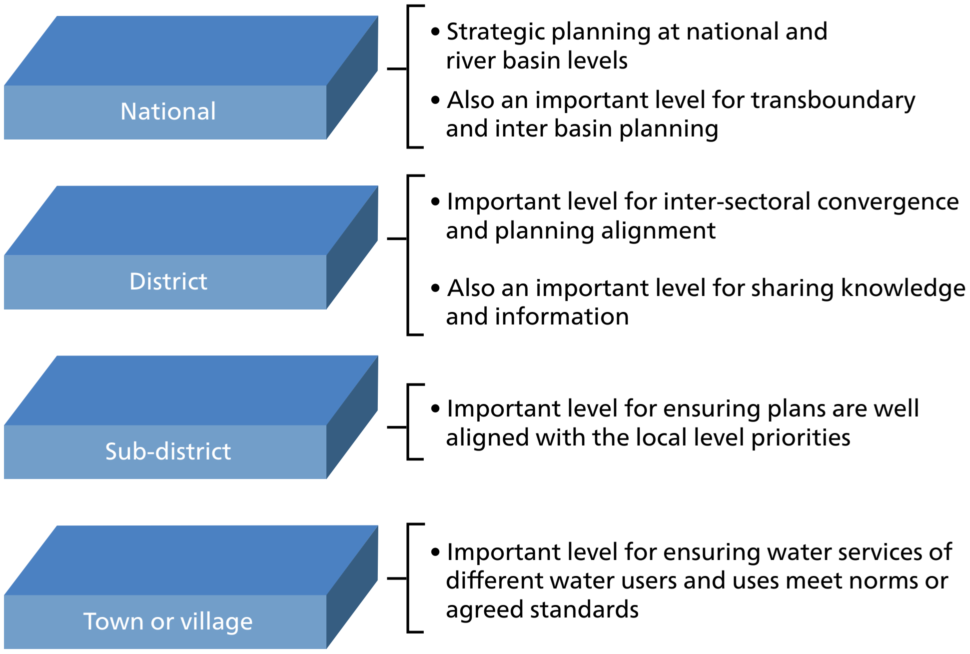
FIGURE 2.1
Different scales of stream delineation



2.2.2 Preliminary identification of issues and concerns

Once the geographical location and temporal and spatial domains of interest have been specified, it is time for preliminary identification of issues and concerns. Typical activities include:

FIGURE 2.2
Typical institutional levels and planning responsibilities



- **Reviewing online information:** This includes reviewing information that is directly or indirectly relevant to the specified domains such as project reports, M&E reports, research papers, and blogs. Useful spatial information is increasingly available from open-access web sites.
- **Stakeholder meetings:** Key-informant interviews with some key stakeholders and focus group discussions with others. In some cases, use of problem-tree analysis to stimulate and structure a facilitated discussion that involves a mixed group of stakeholders. If time permits, a more affirmative discussion around opportunities for addressing issues and concerns may also be illuminating.
- **Field visits** to the specified domain provide opportunities for specialists to interact formally and informally with stakeholders who live and work in these domains and 'frontline' staff working for various water-related government and non-government programmes. Visual assessments and chance encounters during transect walks or visits to, for example, irrigation schemes or water treatment plants can provide insights into the functionality of management systems and the relative importance of different hydrological processes, governance systems and the broader political economy. In addition to visual assessments, photographic surveys can be used to document features like the courses of streams, the condition of water-related infrastructure, the topography of the land, the extent of forest cover and other land uses, and other natural and constructed features of the watershed (EPA, 2008).
- **Review Monitoring and Evaluation data:** If relevant M&E data are accessible, analysis of this data should provide interesting and useful evidence of the extent to which water services are meeting government norms or standards. When it is mapped, this data should also provide information on areas with good service levels and possibly areas or 'hot spots' with substandard services. Similarly, time series analysis should provide information on the influence of, for example,

prolonged periods of drought on the water services of different water users and uses.

2.2.3 Forming a multidisciplinary implementation team

In some cases, responsibility for undertaking water accounting and auditing rests on the collective membership of a multi-stakeholder platform (MSP). In others, the responsibility may rest with one or more of the key stakeholders. In either case, it is quite likely that much of the work will be contracted out to an organization with the appropriate skills and capacity. Whatever the arrangement, the implementation team needs sufficient capacity to undertake both water accounting and auditing. Similarly, a high-level of competence and experience in fields that include information management, facilitation and communication is highly desirable. Good management and coordination of the team is critical. Specialists need to have clearly-defined roles and responsibilities and to be given the space to be specialists. As important, specialists must be able to function well in a multi-disciplinary environment.

Additional considerations when forming an implementation team include:

- Size and disciplinary mix of the team will be linked to such factors as the size of the domains, the number of institutional levels and whether or not key stakeholders play an active role in some or all activities.
- Institutional development is often needed for implementation teams to do their work effectively. Institutional development is often needed to: 1) Create a supportive institutional environment for using water accounting and auditing; and 2) Build capacity for using water accounting and auditing either inside or outside government departments and other 'stakeholder' organizations;
- Building rapport is important so that members of the implementation team can build a good rapport with key stakeholders individually and with the multi-stakeholder platforms. This often takes time and the effort of all involved.
- Mobilisation of a water accounting and auditing implementation team can involve the following: a tendering process; recruitment or contracting of specialists, finding office space, organizing transport and so on. This may take time.

2.2.4 Building partnerships and political commitment

Typical inception activities aimed at building partnerships and political commitment include[18]:

- Preliminary stakeholder identification: A first round of stakeholder identification is advisable, as this will help highlight individuals and organizations that should be consulted during the inception phase. Methods such as a stakeholder analysis, institutional mapping and power analysis can be helpful. Alternatively, a brainstorming session with well-respected water professional can also be a good starting point. The list of potential stakeholders in water accounting and auditing is often very long (see Box 2.3). As a result, it may be helpful to classify stakeholders according to whether they fall into one or more of the following groups:
  - stakeholders that want to be actively involved;

[18] In practice the order of inception activities may vary and some activities may overlap or be carried out in parallel

BOX 2.3
Potential stakeholders in water accounting and auditing

The following is an indicative list of potential stakeholders in water accounting and auditing programmes:

- **various** government departments and agencies;
- **elected** representatives at different institutional levels;
- **non-government** civil society organizations;
- **organizations** with regulatory responsibilities (e.g. pollution control);
- **private sector** organizations;
- **deliverers** and users of water services;
- **research** organizations and academics;
- **media** (traditional and social);
- **potential** users of outputs and those who may be affected by outcomes;
- **managers/custodians** of information;
- **training** or **capacity** building organizations.

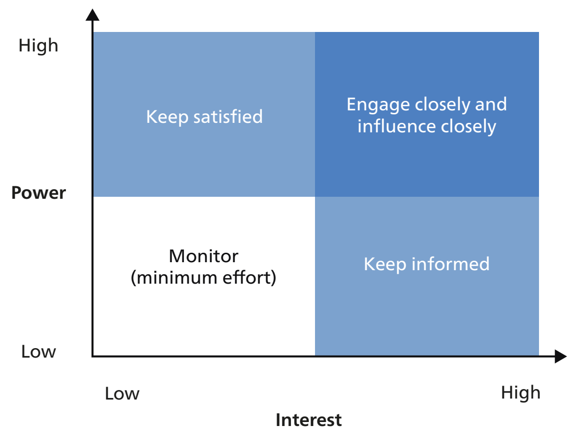
– stakeholder that only want to receive updates and outputs;
– stakeholders that are potential sources of information;
– stakeholders that may fund or part fund the programme;
– stakeholders that are already working on similar programmes;
– stakeholders that have relevant specialist skills, expertise or knowledge.

Alternatively, it is often useful to classify stakeholders according to their potential interest in water accounting and auditing levers and power to instigate change (see Figure 2.3).

- **Initial stakeholder interactions:** Preliminary stakeholder identification and institutional mapping provides a good basis for organizing formal or informal meetings with the stakeholders that are interested in playing a central role in the inception and subsequent phases. It may be necessary to seek advice on the most appropriate person to contact within the 'stakeholder' organizations. Consideration should be given to hiring an independent facilitator who has skills and experience in, for example: ensuring that meetings are well organized and not dominated by a few individuals (see also Box 2.4).
- **Working within or outside government (or somewhere in between):** If a water accounting and auditing programme is initiated from within a government department, it should already have support from relevant civil servants and elected representatives at, for example, the local, district and national levels. However, if the programme is initiated and funded (or partly funded) by an outside agency, it advisable to seek out the support and buy-in of politicians and senior government officials at an early stage. This ensures that these key stakeholders are engaged from the outset and actively involved in decisions relating to, for example, institutional arrangements for implementing the programme.

- It is, of course, possible to initiate and implement a water accounting and auditing programme without government support but this may make it more difficult to access secondary information and to influence policies. However, academics or possibly an activist NGO may feel that the benefits of working outside government (e.g. independence) outweigh the trade-off of having less access to official information and the opportunity of working in partnership with government departments.
- **Creating or reinvigorating a stakeholder platform:** If time and resources permit, work could start during the inception phase on the establishment of a multi-stakeholder platform for key stakeholders with shared interests in investigation and innovation around topics of mutual interest[19]. The aim being that this platform will be one of the main vehicles for stakeholder engagement during the water accounting and auditing processes. In some cases, the starting point could be an existing stakeholder platform or network that might benefit from re-invigoration. More information on the establishment of multi-stakeholder platforms can be found in Section 2.3.

FIGURE 2.3
Different scales of stream delineation



Source: Jones,2011

2.2.5 Developing a provisional communication strategy[20]

Well-organized communication is key element of effective water accounting and auditing. Unless stakeholders are actively engaged and well informed, they will have

BOX 2.4
Facilitating stakeholder dialogue

Stakeholders in water accounting and auditing are far from being a homogeneous group. Often they have serious differences of opinions and even a long history of rivalry and antagonism. Experience has shown that stakeholder meetings are more likely to be productive and constructive if they are facilitated by trained facilitators who are not connected with the stakeholders at the table or the agency that may be funding the water accounting and auditing programme. Or put another way, the facilitator should be perceived as a neutral party who will not contribute his or her ideas to the group. The facilitator should be objective and maintain a broad perspective but should also challenge assumptions, act as a catalyst, generate optimism and encourage the group to maintain a positive attitude towards the water accounting and auditing programme.

[19] The type of stakeholder platform may have different names and forms e.g. a learning alliance (Butterworth *et al.* (2011), a quality improvement collaborative (QIC) (Eppstein *et al.*, 2012).

[20] In the context of water accounting and auditing, communication is understood to be more than exchanging and sharing information, knowledge, experience and views. It also involves debate, negotiation and joint learning that over time has the potential of building trust and social capital.

BOX 2.5
Role of communication

Communication can play a central role in:

- Framing debates, encouraging stakeholder dialogue and getting issues on to the political agenda. This involves raising awareness and influencing the attitudes or perceptions of key stakeholders;
- Encouraging commitments from and endorsements from politicians, opinion formers, community leaders, the media and well-respected specialists or academics for changes in policy and/or practice;
- Securing procedural change changes in the process whereby policy decisions are made, such as opening new spaces for policy dialogue or changes in practice;
- Affecting policy content including changes in legislation or customary practices;
- Achieving sustained behavioural change of key actors of a magnitude that is sufficient to be meaningful.

Source: Jones, 2011

little interest in participating in water accounting or auditing processes and making use of findings and other outputs. The main responsibility for communication may rest with the membership of a multi-stakeholder platform or one of the key stakeholders. Whatever the arrangements, it is likely that many (or possibly all) communication activities will be contracted out to a communication specialist (or even a number of specialists) (see Box 2.5). Typical communication-related activities during the inception phase include:

- **Reviewing existing communication strategies or campaigns:** Communication is a standard component of most government, NGO and/or international agency programmes. Hence, there are almost always lessons to be learned from reviews of ongoing programmes in terms of what is working well or not so well.
- **Culture of sharing information:** In general, communication will be most effective during a water accounting and auditing programme if a culture of sharing information can be created. Ideally communication should be open, inclusive and respectful. Even if this is not possible in short term, this should be the long-term objective.
- **Choice of language:** Selecting an appropriate language (or mix of languages) may not be a major issue in some countries or specified domains but in others this may be a critical issue.
- **Choice of communication technologies and media:** Similar to the above, it may be necessary to select communication technologies or media that do not alienate or exclude certain stakeholder groups or the wider public. This said, new communication technologies and social media should certainly be considered such as Twitter, Skype, YouTube.
- **Segmentation and targeting:** Consideration can be given to the potential benefits of using segmentation and targeting tools developed by the marketing industry to separate groups according to the reasons they might reject or accept water accounting and auditing outputs.

- **Communication costs:** Ideally, communication activities and inputs to water accounting and auditing programmes should have their own budget that is tied to achieving the objectives of a communication strategy.

2.2.6 Preparation of an outline water accounting and auditing plan

Towards the end of the inception phase, it should be possible to produce a well-structured outline plan. Typical activities include:

- **Needs assessment(s):** Rather than being prescriptive, in most cases water accounting and auditing should be adaptable, flexible and planned on the basis of needs assessments and assessment of priority challenges faced within specified domains of interest.
- **Visioning** can be used by key stakeholders to discuss what they would like to achieve by the first, and subsequent, cycles of the water accounting and auditing programme. Visioning also helps to clarify the interests that stakeholders have in the programme and along with any major concerns. Note that visioning processes are, in general, more productive if they are well structured and facilitated.
- **Methods, tools and software packages:** Many well-proven methods, tools and software packages can be used as part of water accounting and auditing. Some are described in this sourcebook. Additional guidance can be found online[21]. The challenge is to select methods, tools and software packages that fit the needs of the planned water accounting and auditing programme. As a general rule, it is best to use methods, tools and software packages that the implementation team and key stakeholders already know well.
- **Scheduling and sequencing of activities:** Careful scheduling and sequencing of water accounting and auditing activities is required if they are to be mutually supportive and synergistic. In particular, it is advisable for integrated analysis and modelling to be scheduled and sequenced it as an integral part of water accounting and auditing as opposed to being a rather important 'add-on'.
- **Institutional arrangements:** As mentioned above, important decisions need to be made regarding, for example, whether to work within or outside the government system, or somewhere in between; whether to engage fully with stakeholders at all institutional levels; whether to set up a core team to coordinate and lead on certain or all activities and so on.
- **Information management:** Typically water accounting and auditing involves acquisition, quality controlling, analysis, interpretation and sharing of large amounts of data and information[22]. Resources and information management skills are needed to make sure that data and information are available when and where required in forms and formats that meet the needs of stakeholders and other users. Information management is also about knowing what information to gather, knowing what to do with the information when you get it, knowing

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[21] Additional sources of guidance include:
http://www.toolkit.net.au/Tools/Default.aspx
http://www.osgeo.org/
http://www.fao.org/nr/water/infores_databases.html
http://csdms.colorado.edu/wiki/Hydrological_Models
http://www2.epa.gov/science-and-technology/water-science-resources#tools
http://resources.arcgis.com/en/communities/hydro/

[22] The terms *data* and *information* are interrelated and often used interchangeably. In general, data refers to raw facts, figures, observations, etc. in different forms and formats. Whilst information refers to data that has been processed or analysed in ways that make it meaningful and useful to whoever accesses and uses it.

what information to pass on and, knowing how to value the resultant use of the information[23]. It is also crucial that sufficient metadata[24] is made available so that stakeholders can make sense of the data and information and make an informed judgement as to its usefulness.

- **Mitigation of risks:** Water accounting and auditing is not without risks. For example, it is also possible that the whole process will prompt stern resistance from some stakeholders who feel threatened by it. Or the quality and accessibility of secondary information may prove to be less than adequate. Whatever the case, identification of potential risks, and a plan for mitigating these risks, is recommended.
- **Funds and fund flows:** The overall cost of water accounting and auditing programmes varies enormously with, for example, the scale and ambition of the programme, the cost of contracting an implementation team, the need to collect primary information and, in some cases, the need to pay for secondary information. If funds are not available to meet the overall cost, this is the stage to seek additional funds or reduce the level of ambition of the planned programme.

2.3 STAKEHOLDER ENGAGEMENT

2.3.1 What is a multi-stakeholder process?

Typically, multi-stakeholder processes[25] are an important component of water accounting and auditing that cut across most activities. Their precise role varies but, in general, they contribute to some combination of social and institutional learning, conflict mediation or resolution and collective decision-making. There is also the likelihood or intention that active stakeholder engagement will ensure that cycles of water accounting and auditing focus on the priorities of key stakeholders and, as important, outputs and recommendations will be owned, or at least not ignored or rejected, by key stakeholders.

However, stakeholder engagement does not radically change the opportunities that exist for addressing priority issues and concerns or the nature of tough political choices that may have to be made especially in areas of increasing water scarcity (e.g. with regard to allocation or re-allocation of limited water resources). So arguably, the virtue of multi-stakeholder processes lies more in procedural equity and ownership rather than any significant improvement in the quality of decisions that might emerge (Green, 2011). As a result, it is usually a mistake to assume that merely getting stakeholders together from time to time will produce better outcomes in terms of identification of opportunities for solving priority problems (see Box 2.6).

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[23] When deciding how much information to collect, the concept of appropriate imprecision is often useful. Appropriate imprecision recognizes that in conventional water assessments, much of the information collected has a degree of precision that is really unnecessary and/or is inconsistent (in terms of precision) with the other information that is being collected.

[24] Metadata is data that describes other data. Meta is a prefix that in most information technology usages means "an underlying definition or description." For example, metadata for a water governance report could include: author(s) or organization, date drafted, name of report and analytical framework used. Or metadata for rainfall data could include: responsible organization, number, type and grid references of rain gauges, methodology used to convert point measurements to areal estimates, an estimate of uncertainties and so on.

[25] In this sourcebook the generic term 'multi-stakeholder processes' refers to a whole range of different approaches to stakeholder dialogue, collaboration or engagement such as round tables, learning alliances, communities of practice, quality improvement collaboratives.

The rationale behind multi-stakeholder processes is that complex problems require solutions that are well adapted to any given social, political and cultural context (see Figure 2.4). These solutions are more likely to emerge when diverse stakeholders are able to meet, share experiences, learn together and contribute actively to decision-making processes. However, the ultimate success of multi-stakeholder processes often lies in developing the collective commitment to turn promising ideas and plans into action. As such, multi-stakeholder processes are (After Wageningen UR, 2013)[26]:

- Processes that aim to involve stakeholders in improving situations that affect them.
- Forms of social interaction that enable different individuals and groups, who are affected by an issue or concern, to enter into dialogue, negotiation, decision-making and relevant collective action.
- About getting government staff, policy-makers, community representatives, scientists, business people and NGO representatives to think, work and learn together.

However, multi-stakeholders processes are not a panacea (Woodhill, 2010). Nor are they a harmonious model of change (i.e. by simply coming together stakeholders

BOX 2.6

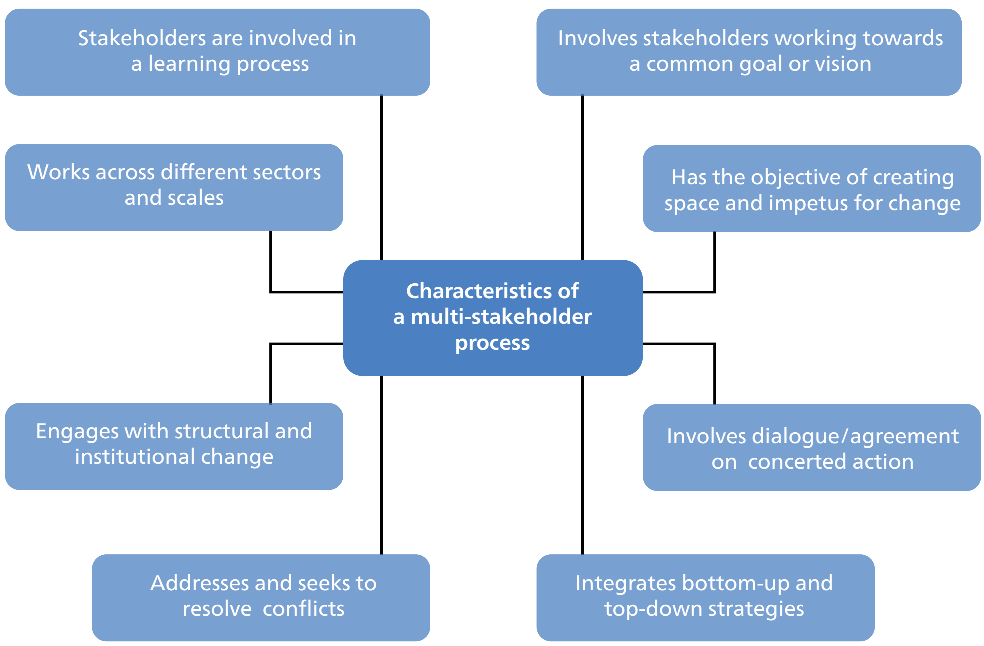
Added value of stakeholder engagement

For stakeholder engagement to add value to water accounting and auditing, stakeholders must be ceded the power to influence decisions and choices. So even if the final decision or choice may rest with politicians or democratically-elected officials or bodies, stakeholders will only engage actively in a multi-stakeholder process if they believe that they can influence processes, decisions and choices that may affect them.

Source: Green, 2011

FIGURE 2.4

Typical characteristics of a multi-stakeholder process



Source: Wageningen UR, 2013

[26] More information on stakeholder engagement, multi-stakeholder processes and platforms can be found on this Wageningen University portal (http://www.mspguide.org/tools-and-methods).

achieve consensus). Inevitably, processes of stakeholder dialogue and concerted action start with different perspectives that may conflict or involve some level of mistrust and misunderstanding. In addition, political science reminds us that people do not 'come to the table' as blank slates, but with an agenda that can have a beneficial or damaging effect on dialogue or concerted action (Warner, 2006). Particularly in areas of increasing water scarcity, the dominance of allocation issues is likely to prompt heated dialogue and possibly negotiation (about how the 'cake' is cut) rather than, for example, discussions that focus on inter-sectoral integration, alignment and/or nesting of plans ('baking the cake together'). In these circumstances, there is also the risk that more powerful stakeholders will attempt some form of capture of the resources ('taking the cake').

Clearly, multi-stakeholder processes are not suited to all contexts. While explicitly starting with diversity, multi-stakeholder processes have a tendency to oversimplify challenges when searching for consensual solutions. The net result is that agreed solutions may be simplistic and incapable of delivering desired outcomes. Similarly, in situations where diversity and debate are not part of existing societal or cultural norms, multi-stakeholder processes have a significant risk of failure.

2.3.2 Objectives of multi-stakeholder processes

Specific objectives of multi-stakeholder processes can include:

- Ensuring that key stakeholders have the power to influence decisions and choices throughout cycles of water accounting and auditing process. In so doing, increasing the likelihood that: 1) Key stakeholders take ownership of water accounting and auditing outputs and outcomes; and 2) Key stakeholders are less likely to reject findings outputs and recommendations that challenge accepted wisdom or current policies.
- Ensuring that the water accounting and auditing makes good use of existing knowledge, especially local knowledge. Also to encourage stakeholders to search out flaws or gaps in water accounting and auditing findings, outputs and recommendations.
- Ensuring that existing information and knowledge is made accessible to and shared among stakeholders. In so doing, ensuring that issues relating to divergent or contested data sets, opinions or values are addressed.
- Ensuring that water accounting and auditing stakeholder platforms either build on or link to (rather than challenge or threaten) existing stakeholder platforms.
- Given the fragmented nature of roles and responsibilities across the water sector, ensuring that a comprehensive range of issues, opinions or perspectives are addressed or evaluated.
- Providing key stakeholders with an opportunity for shared learning and, if relevant, hands-on training and capacity-building.
- Reducing the costs and/or improving the value for money of water accounting and auditing.

2.3.3 What is a multi-stakeholder platform?

A widely accepted definition defines a multi-stakeholder platform as a decision-making body (voluntary or statutory) comprising different stakeholders who perceive the same resource management problem, realise their inter-dependence for solving it, and come together to agree on action strategies for solving the problem' (Edwards and Stein, 1998). Some typical principles and aims of multi-stakeholder platforms are listed in Table 2.1.

A multi-stakeholder dialogue is not just a conversation, but an interactive approach to getting things done in 'a contrived situation in which a set of more or less interdependent stakeholders, in a water resource or a water services delivery system, are identified and invited to meet and interact in a forum for conflict resolution, negotiation, social learning and collective action (Warner, 2005).

In the case of water accounting and auditing, stakeholder dialogue can result in commitments to: 1) Sharing secondary information; 2) Working in concert on activities such as updating, gap-filling and expanding information bases; 3) Agreeing to work collaboratively on the analysis and interpretation of biophysical and societal information and evidence; 4) Agreeing to resolve conflicts if and when they arise; and 5) Agreeing to learn lessons from piloting new ideas or innovations.

BOX 2.7
Effective multi-stakeholder processes require funds, time and other resources

Typical resource inputs include:

- costs, time and office space for some kind of secretariat;
- time input of steering committee;
- support from a professional facilitator;
- costs of formal events e.g. workshops, meetings, exposure visits, capacity building etc.;
- costs of, for example, engaging a core team to lead a water accounting and auditing process;
- cost and time requirements of active formal and informal stakeholder engagement in the water accounting and auditing process;
- documentation and communication costs of, for example, setting up and managing a web site, communicating with the media, wider public, etc.

Source:Wageningen UR, 2013

TABLE 2.1
Typical principles and aims of multi-stakeholder platforms (MSP)

MSP Principles	Aims
Inclusiveness and participation	To encourage: 1) Participatory processes that are genuine, predictable and maintained over time diverse and/or 2) Stakeholder representation that is inclusive and ensures that less powerful groups have a "voice"
Transparency and accountability	To ensure that processes of stakeholder dialogue and concerted action are transparent and stakeholder representatives can be held to account
Legitimacy	To ensure that platforms at different institutional levels are legitimate e.g. constituted as statutory bodies or as part of a government order
Effectiveness	To develop processes or concerted actions that really makes a difference e.g. in terms of solving problems or improving water services
Shared learning	To encourage stakeholders to work collectively on the identification of causes of problems and the potential utility of opportunities for solving these problems. This is particular important when water accounting and auditing findings challenge accepted wisdom
Common information base	To encourage stakeholders to establish a common information base (or virtual observatory). The broader objective being that stakeholders have the same information an d evidence as a starting point for dialogue.A
Efficiency	To make sure the ends (e.g. outcomes) justify the means (e.g. costs, trade-offs, time)
Equity	In part to ensure that benefits are not captured by more powerful groups and in part to reduce the risks means of conflict

BOX 2.8

Questions that may need to be addressed when initiating and building a multi-stakeholder platform (MSP)

- How formal will the MSP membership be – how are members admitted (or not)?
- Will the MSP be concerned only with water accounting and auditing or will it have a wider remit?
- Will the MSP have an interest in both water accounting (i.e. biophysical and technical aspects of water management) and water auditing (i.e. societal aspects of water management)?
- How will a domain of interest and issues of mutual interest be identified/specified?
- Are MSP platforms needed at different institutional levels and if platforms are needed at different levels how will responsibilities be shared?
- How are formal and informal MSP activities be funded, and how will costs and benefits be shared?
- How will the MSP communicate and share information and ideas at each institutional level, between levels and more widely (e.g. workshops, reports, e-mails, text messages, web sites, social media)?
- How will the MSP awareness-raising and capacity-building requirements be assessed and addressed?
- How will a comprehensive mapping of stakeholders and governance systems in a specified domain be undertaken?
- What research or specialist support activities will the MSP need, and how should this be commissioned or contracted?
- How will inter- and intra-organizational learning be assured?
- How will the MSP engage with powerful or influential stakeholders outside the MSP?
- How will the MSP monitor and evaluate its own performance and the performance of support organizations?
- How will learning processes be documented to ensure that learning is optimised, and shared widely?

It is important to recognize that multi-stakeholder processes and/or platforms don't just happen (WageningenUR, 2013). They need to be created, maintained and facilitated. There are many practical aspects related to setting them up, such as who to involve, the methodologies that can be used, the phases they go through and facilitation and process capacities required. It is important also to note that stakeholders are likely to have a wide array of interests and motivations and differing levels of power and influence. In such cases, consensus is the exception and the behaviour of some stakeholders may be opportunistic and disruptive. Hence skilled facilitation is often needed to ensure that multi-stakeholder platform members are respectful and that lines of formal and informal communication are maintained between all stakeholders (see Box 2.8).

2.3.4 Appropriate levels of stakeholder engagement

Given that the transaction costs of active stakeholder engagement can be high, it is advisable that the level and complexity of stakeholder engagement is appropriate to a given context. As a general rule, stakeholder engagement in areas of no or limited water scarcity is confined to stakeholders at different institutional levels within a sector (e.g. WASH or irrigation). As there is no or very limited inter-sectoral competition for water, user groups and stakeholder platforms focus on 'within sector challenges' such as secure and equitable access to services at all time by all users especially marginalised social groups (see Table 2.2). In contrast, in areas of significant or rapidly increasing water scarcity, stakeholder engagement becomes increasing inter-sectoral and the solutions to many (possibly most) problems require inter-sectoral dialogue and concerted action at different levels and scales.

It is well reported that user groups and stakeholder platforms tend to fail once the funding for institutional support mechanisms runs out[27]. The lesson is that long-term funding is needed to establish and maintain user groups and stakeholder platforms but, to keep costs down, the level and complexity of these user groups or platforms should

TABLE 2.2
Influence of water scarcity on types of stakeholder engagement

Water scarcity status (in specified domain)	Typical planning and management challenges	Types of stakeholder engagement	Types of water user group and/or stakeholder platform
No significant water scarcity	Most challenges can be solved via sectoral dialogue and action e.g. • Ensuring equitable delivery of services to all users / social groups • Maintaining the functionality of water supply infrastructure • Keeping down the transaction costs of stakeholder engagement • Source protection including steps to avoid/ mitigate pollution	Predominantly sectoral engagement i.e. each line department or programme has it's own user groups or stakeholder platforms. Inter-sectoral stakeholder engagement restricted to e.g. • Inter-departmental coordination committees at national and intermediate levels • Planning and managing extreme events e.g. floods, droughts	At the local level: • Village water and sanitation committees • Water use associations • Watershed development committees At higher levels: • Informal or formal networks involving government, non-government , private sector and academic organisations • Planning and budgeting committees at intermediate and national levels
Significant water scarcity	Many (possibly most) challenges can only be solved via inter-sectoral dialogue and concerted action e.g. • Policies and programmes leading to increased consumptive water use • Falling groundwater levels and competitive well-deepening • Upstream-downstream conflicts over access to water	A combination of both sectoral and inter-sectoral stakeholder engagement is required to solve many (possibly most challenges). Increasing involvement of local government and other democratically elected bodies	In addition to the use groups and platforms listed above • Village, district or regional level councils or development committees • River basin organisations, river commissions, aquifer management organisations etc • Informal or formal networks with an interest (or stake) in inter-sectoral water management and/ water services delivery

[27] For example RWSN (2009) stresses the need for long-term support for local water user committees

be appropriate. Or put another way, a higher level of funding may be required in areas of high water scarcity, and a lower level in areas that are experiencing no or very limited water scarcity.

2.3.5 Stepwise approach to forming a multi-stakeholder platform

The first step in creating a multi-stakeholder platform (MSP) to support a water accounting and auditing process is to establish whether or not key stakeholders: 1) Have reasons for being directly involved in water accounting and auditing process. (e.g. mandates, responsibilities); and 2) Believe or see merit in engaging actively in a water accounting and auditing process. Even if these two conditions are met, leadership and effort is needed to form a new MSP or possibly to revive and reinvigorate an existing MSP. As with any group activity, momentum for a new initiative is often provided by one or two key individuals with backing from their superiors or professional networks. To form an MSP, someone or an organization has to take the lead. Ideally, at least one national-level organization will agree to host an MSP; i.e. to provide the initial support, space and resources needed by a coordinator or facilitator.

The way an MSP is set up can spell success or failure for the initiative right from the start. It is important to note that the nature and characteristics of an MSP can be affected by markets, politics, technology, people, programmes and policies both within and beyond the boundary of the MSP. Similarly the MSP in turn may influence activities and policies both inside and outside its boundaries.

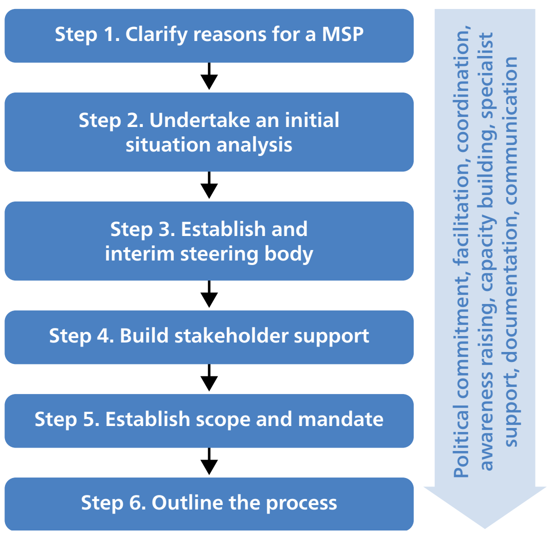
The following is a typical stepwise approach to establishing an MSP (After WageningenUR, 2013):

Step 1: Clarify the reasons for the proposed MSP. Ideally a wide-range (if not all) the key stakeholders with a significant water-related stake in the specified domain(s) are involved in the process of clarifying the reasons for an MSP (see Figure 2.5). Questions to be asked include:

- What are the motivating factors?
- What drives people? What are their major concerns?
- How will an MSP enhance what is already being done?
- Is it worth the effort?

During this step, it is important to focus on real needs and priorities and how best to utilise available resources effectively. While external resources will often be critical, it is usually counterproductive to create an MSP just to chase or utilise programme funding.

FIGURE 2.5
MSP establishment stepwise process



Step 2: Undertake initial situation analysis (stakeholders, issues, institutions, power and politics). The second step usually involves the instigators of the MSP initiative undertaking initial stakeholder and institutional analysis. The aims being to

explore how historical changes have occurred in the specified domain, why different things are the way they are, and why groups and individuals hold their particular perspectives on water-related matters. This should provide insights into why key stakeholders might welcome, or even be hostile to, a water accounting and auditing process.

It is likely that some key stakeholders will have an institutional memory of earlier MSP experiences. It is also likely that they will have an opinion about which MSPs were or were not successful. This historical information along with the outputs from stakeholder and power analysis should provide insights into:

- Stakeholders who are key or critical to the success of the MSP or are working to achieve similar outcomes to those of water accounting and auditing.
- Stakeholders who have particular formal or informal powers.
- Stakeholders who may be blockers or floaters.
- Stakeholders who may have a particular role to play in some aspect of water accounting and auditing.

Step 3: Establish an interim steering body. An interim steering body is often needed to get an MSP off the ground. Considering it as 'interim' often enables things to get started by removing some of the politics of 'who is in control'. Beginning with interim arrangements also gives key stakeholders a chance to see how things develop and then make a more informed-decision as to the final coordination and management responsibilities. During this step the following questions need to be addressed:

- **What type of steering body is appropriate?** It is important not to confuse an 'advisory body' with a 'management body' as members will grow weary and withdraw if their well-considered advice is repeatedly ignored.
- **Who will be part of this interim steering body?** Issues of power, gender and institutional dynamics should be recognized.
- **What is the life span interim steering body?** The expected life and role of the interim steering body should be determined and communicated to all stakeholders.

Step 4: Build stakeholder support. MSPs require significant support from many different players. Stakeholders need to be confident that not only are their concerns and suggestions being listened to and considered, but that the MSP will deliver for the whole community, and not just for a few people who have more power than others. Being open and inclusive also reduces the possibility of the process being undermined later on by those who were not involved at the start. Commitment from stakeholders and ownership of the process are essential for success. A few key factors to consider are:

- Cast your net wide (e.g. water users, local government, NGOs, line departments, CBOs).
- Publicise the intent of the MSP. Actively and consistently welcome contributions and comments.
- Spread the knowledge. Get each person that is already involved to discuss the proposed development of a MSP with ten others (business, government, friends, family, community groups) over the next fortnight.
- Put a strong emphasis on active participation. Ensure stakeholders have a voice and are listened to. Ensure that everyone feels there is space for their ideas and concerns to be heard and taken on board.

- Ensure well-facilitated processes that achieve results within an agreed time frame. Focus on tangible results and early 'wins'.
- Ensure commitment to shared responsibilities for implementing and funding agreed follow-up activities. If relevant, reimburse people appropriately for time and costs incurred.
- Those initiating and organizing multi-stakeholder processes need to realise that this is just one of many other things people are involved in and to which they are committed. Sometimes it may be necessary to go ahead with less than ideal levels of participation.

Step 5: Establish the scope, mandate and stakeholder expectations. It is important that key stakeholders reach consensus early on about the boundaries of the MSP. If the scope is too wide or too narrow little may be achieved. It is also very important to reach agreement on the mandate for the MSP. Is the MSP officially sanctioned by government? Do some groups or institutions believe the process is legitimate while others do not?

In a complex multi-stakeholder situation it is easy for very different interpretations and expectations to evolve amongst the different groups. While this difficulty often cannot be fully overcome, the more effort that goes into reaching an initial shared understanding the better. Similarly, it should be recognized that over time the scope and mandate of an MSP may change. If it does, once again it is important for this to be explicit and for it to be understood by the stakeholders involved.

Step 6: Outline the process, time frame, institutional requirements and resource needs. In the setting-up stage it is important to be as clear as possible about the overall process and time frame of the MSP and about the institutional requirements. Also the principles of the MSP should be shared and monitored together. The different stakeholders need to know what sort of meeting, workshops and committees will be held and when. The process must be transparent so that feelings of being manipulated don't emerge.

It is also important to recognize the importance of the differences between formal multi-stakeholder processes and the informal (or less formal) stakeholder dialogue and concerted actions that may take place, for example, as follow-ups to formal meetings.

2.3.6 Key issues in stakeholder engagement[28]

A number of key issues relating to stakeholder engagement are discussed in this section. These include issues of scale and legitimacy, cooperation and collaboration, integration and negotiation for consensus.

First, the geographical scale of water accounting and auditing and the availability of resources such as time and funds have a bearing on the level of stakeholder engagement that might be possible and also on the ambition and complexity of the MSP. In this regard it is important to note that creating a dynamic MSP that has a high-level of key stakeholders' commitment takes time, patience and perseverance especially if the platform is functioning at a number of institutional levels.

[28] This section draws on South Africa's Guidelines for catchment management strategies: http://www.award.org.za/file_uploads/File/CMS_2008_lowres.pdf

Second, the legitimacy of an MSP can be an issue. An MSP should not be just a discussion group but a practical body that, for example, seeks to apply research to pressing biophysical or societal problems. It is important for the instigators of an MSP to ask why they want to engage stakeholders and why they are interested in joining an MSP. If the conscious decision is to proceed with water accounting and auditing that is based on stakeholder engagement, it is important also to decide whether an MSP should concentrate on water accounting and auditing as a stand-alone process, or as part of a broader planning and programme implementation process. If it is the latter, attention should be given to the legitimacy of the MSP to make choices and decisions; many of which may be highly political. In either case consideration should be given to whether the stakeholder engagement:

- is inclusive, transparent and fair;
- is representative of the specified domain based on biophysical and societal criteria;
- addresses power and capacity differences and/or asymmetries;
- makes allowances for language, gender, age, ethnic and other social differences;
- gives special attention to disadvantaged or marginalised groups to ensure that they can participate or are well represented.

Effective water accounting and auditing requires cooperation and collaboration among stakeholder groups and specialist support organizations. An important point to recognize here is that collaboration is more than cooperation because it involves an 'active joining together' of resources and effort towards a particular shared goal. Collaboration is thus a social process based on:

- participation and dialogue;
- formation of partnerships;
- sharing of information;
- investment in ideas and processes of learning;
- consensus and negotiation between various stakeholders and stakeholder groups;
- emphasis gaining insights from the water auditing that learn from the past and lead to measurable tangible improvements in the way things are done in the future;
- learning based on a better understanding and recognition of differences (and similarities) between the perspectives, opinions and practices of different stakeholders.

Within a specified domain, water accounting and auditing takes a holistic approach to assessing: 1) Trends in water supply, demand and use in time and space; and 2) The complex governance processes and mechanisms that determine how political, economic and administrative authority is exercised and water is allocated and managed.

To do this effectively, an integrated approach, involving a diverse range of stakeholders is required. But what does this mean in reality? On the one hand this involves regular formal and informal contact as part of an MSP and concerted action to collect and analyse information. But what happens, if stakeholders cannot agree on the veracity of the information, the analysis and interpretation of findings and/or the recommendations of a water audit? One option is to collect more information, or possibly to devise an independent study that decides which (if any) of the opposing positions is correct. Another option is to use a structured negotiation approach that is based on the 'negotiation for consensus' framework. In the event that this does not lead to a consensus the next best option is for stakeholders to 'agree to disagree' and for this and the divergent opinions to be documented[29] . Such negotiations become particularly important when dealing with divergent or opposing views concerning 'wicked' problems (i.e. problems that are dynamic, complex, encompass many issues and evade straightforward, lasting solutions) (Howes and Wyrwoll, 2012).

2.3.7 Capacity-development

Ultimately, the success of water accounting and auditing programmes depends upon the competence, experience and hard work of those responsible for implementing the programme. However, in many countries, the availability and capacity of the specialists needed to support water accounting and auditing programmes is often limited. Especially in the following fields hydrological sciences, informatics, mathematical modelling, spatial analysis, policy influencing and communication. Even when capacity exists, specialists often tend to be academically minded and more accustomed to working at the national or regional level. While inputs from well-respected 'academics' can be valuable, this is no substitute for inputs from younger or possibly less experienced specialists who are willing and able to: 1) Work at the intermediate and local levels; and 2) Commit significant time and energy to a water accounting and auditing programme.

While this lack of capacity is often well known, governments and international agencies often prefer to invest for example, in information systems rather than the capacity of potential users of these systems. In addition, capacity-development is often handled as a one-off activity with limited follow-up. A more effective approach is often to empower and encourage organizations and/or their personnel to take control of solving their own capacity problems. When successful, this creates institutions that are better able to improve and sustain their capacity. It also increases the likelihood that building the capacity of individuals will be regarded as being as important as any technical intervention.

Finally, it is very important that everyone involved in the implementation of water accounting and auditing programmes receive financial rewards and incentives that both encourage their long-term commitment to the programmes and their interest in self-improvement through, for example, formal or hands-on training.

2.3.8 Public participation in water accounting and auditing

Democratic systems require that people who may be affected by a decision be given the opportunity to be part of the decision-making process. In some cases, this level of participation in water accounting and auditing may not be necessary because the MSP may include elected representatives. Alternatively, recommendations from a water accounting and auditing process may be approved or adapted by an elected representative (e.g. a minister) or a legislative assembly (e.g. a district or river basin council). Of course, if stakeholder engagement and communication is ineffective, there is always the risk that outputs and recommendations will be regarded as an academic exercise that has little to do with mainstream political processes. However, in cases where water accounting and auditing is an integral part of a decision-making process, it is important that consideration is given to different levels of participation by civil society.

[29] For more information on negotiation theory and practice see: Alfredson and Cungu (2008) http://www.fao.org/docs/up/easypol/550/4-5_negotiation_background_paper_179en.pdf and Dore *et al* (2010) http://data.iucn.org/dbtw-wpd/edocs/2010-006.pdf

The South African International Association for Public Participation identified different types of public participation that they call spectrum[30] (see Table 2.3). This classification system highlights different levels of public or civil society engagement in activities such as water accounting and auditing along with a range of techniques that can be used to structure and encourage public participation.

TABLE 2.3
The public participation spectrum

Increasing level of public engagement →

Inform	Consult	Involve	Collaborate	Empower
Public participation goal				
To provide the public with balanced information to assist them in understanding the problem, opportunities, solutions and alternatives	To obtain public feedback on analysis, alternatives and decisions	To work directly with the public throughout the process to ensure that public concerns are consistently understood and considered	To partner with the public in each aspect of the decision making process including the development of alternatives and the identification of preferred solutions	To place final decision-making in the hands of the public
Promise to the public				
We will keep you informed	We will keep you informed, listen to and acknowledge concerns, aspirations, provide feedback on how public input influenced the decision	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how the public input influenced the decisions	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible	We will implement what you decide
Examples of techniques				
• Fact sheets • Web sites	• Public comment • Focus groups • Surveys • Public meetings	• Workshops • Polling	• Citizens advisory committees • Forums • Consensus building • Participatory decision-making	• Citizen juries • Ballots • Delegated decisions

2.4 Tips and tricks

- If stakeholder engagement is to be meaningful, stakeholders should have the power to influence decisions regarding, for example, the location and scope of a water accounting and auditing programme; responsibilities for leading the process; interpretation of findings and so on.
- Active participation of well-informed stakeholders, who communicate effectively with each other on a regular basis, contributes significantly to the accuracy, relevance and adoption of water accounting and auditing findings, outputs and recommendations.
- Be clear from the outset on the objectives of using a stakeholder engagement model, but don't be surprised if objectives and expectations change over time.
- While formal multi-stakeholder platform meetings and events are important,

[30] The Spectrum Framework is available at: www.iap2.org/spectrum.html.

stakeholder dialogue and concerted action between meetings often generate the most interesting water accounting and auditing findings.

- Facilitation of events is needed to ensure that contentious issues are handled with sensitivity and more powerful individuals or groups do not dominate discussions and decision-making.
- Be aware that some problems that crop up during stakeholder dialogue may be ‘wicked’ in nature and, as such, there will be no obvious solution, and attempts to tackle these problems may create new unexpected problems, externalities or trade-offs.

3. Water accounting

3.1 AIMS OF THIS SECTION

In most cases, it is recommended that water accounting and auditing are implemented in a number of iterative cycles (see Figure 1.4). Typically, during each iterative cycle, the initial focus of water accounting and auditing is parallel to mutually supportive, biophysical and societal assessments, analysis and modelling with crosscutting activities such as stakeholder analysis and coordination of data acquisition as appropriate. Subsequently, in each iterative cycle, the emphasis of both water accounting and auditing shifts to integrated analysis and modelling. This section describes typical water accounting activities and stepwise processes that can be used in parallel with water auditing. Subsequent integrated analysis and modelling activities and processes are described in Section 5.

The key aims of this section are to describe the: 1) Detailed water accounting planning that takes place at the beginning of each cycle of water accounting (and auditing); 2) Activities that take place during the biophysical information acquisition and management phase; 3) Targeted[31] biophysical assessments that aim to understand the hydrology and current status and trends in water supply and demand in the specified domain; and 4) Multi-scalar analysis and modelling that quantifies water flows, fluxes and stocks in specified domains.

3.2 WATER ACCOUNTING STEPWISE PROCESS

As stated above, the initial focus of each iterative cycle of water accounting is firmly on understanding the: 1) Hydrology and current status and trends in water supply and demand in the specified domain(s); and 2) Underlying causes of biophysical issues and concerns as highlighted and prioritised by key stakeholders (see Figure 3.1). The rationale is that it is best to focus initially on getting a basic understanding of, for example, the main hydrological processes (see Box 3.1); the capacity and status of water-related infrastructure; the agricultural and other land use systems; and the water demands of different water users and uses in the specified domain(s) before moving on to multi-scalar analysis and modelling. Experience has shown that this systematic

BOX 3.1
Importance of hydrological and hydrogeological processes and interactions

Inter-linkages between rainfall, surface water, groundwater, soil moisture and rates or processes of evaporation from different land uses are of critical importance, and are not fully reflected in many national water management plans. Groundwater and surface water are ultimately part of the same resource, and cannot be regarded as alternative sources. Attempts to increase the efficiency of water use in a specific domain without a clear understanding of the impact on systemic water balances may lead to unintended and undesirable results either locally or downstream

Source: FAO, 2012

[31] Targeted, in this context, refers to activities that have a well-defined purpose and objectives. These activities could focus on problems, concerns of issues of key stakeholders or, more affirmatively, they could also focus on the assessment of opportunities that have potential for achieving specified outcomes.

FIGURE 3.1
First four phases of a typical water accounting process

1. Detailed water accounting planning
   - For the first iterative cycle, finalise planning activities started in the inception phase. For subsequent iterative cycles take account of lessons from previous cycle(s) of water accounting & auditing e.g. modify/adapt domains, strategies, methodologies etc;
   - Stakeholder dialogue and concerted action leading to prioritisation of next cycle of activities, assessments and analysis;
   - Agreement on expected outputs of next cycle of activities.

↓

2. Biophysical information acquisition & management
   - Combined biophysical and societal Information needs assessment;
   - Identification of secondary information sources for current cycle. If relevant, planning & implementing a programme of primary information collection;
   - Information acquisition, processing and quality control;
   - Storage and sharing (e.g. data, metadata, maps, reports, photographs, etc).

↓

3. Targeted biophysical assessments
   - Plan and implement targeted assessments of current status of and trends in, for example: water resources depletion; land management systems; water supply, storage and treatment infrastructure etc;
   - Compare/triangulate findings/outputs against information from independent sources;
   - Share and discuss outputs/findings of each assessment with stakeholders. Resolve differences of opinion and take account of feedback.

↓

4. Multi-scalar analysis & modelling of water flows, fluxes and stocks
   - Use outputs from targeted assessments as a basis for selecting, setting up, calibrating and validating hydrological models;
   - Use empirical data collected and models to support e.g. multi-scalar fractional and water balance analysis;
   - Produce, tabulate and map multi-scalar estimates of water flows, fluxes and stocks under different conditions;
   - Consolidate, share and discuss findings and outputs with stakeholders.

step-by-step approach tends be more efficient (in terms of costs and time) and produce better outputs.

Typically, each iterative cycle of the accounting process has four main phases that start with detailed water accounting planning (see Figure 3.1). The general recommendation is to actively engage stakeholders in all these phases and to ensure that water accounting and auditing are mutually supportive. The latter can be achieved partly by crosscutting activities such as coordination of information acquisition and management.

3.3 DETAILED WATER ACCOUNTING PLANNING

3.3.1 Revisit and update water accounting plans

At the beginning of the first iterative cycle of water accounting (and auditing), it is usually necessary to revisit and update plans that may have been produced as part of the inception activities described in Section 2. Reasons for this include:

- New stakeholders may have joined the multi-stakeholder platform that was formed or reinvigorated during the inception phase.
- The water accounting (and auditing) implementation team will have been mobilised.
- Available funds and institutional arrangements for implementing the programme may be different to those originally envisaged during the inception phase.
- Stakeholder meetings at the beginning of a water accounting and auditing programme raise awareness that the programme has started. Especially, if the meetings are reported in the media and on social networks.

At the beginning of subsequent iterative cycles of water accounting and auditing, it is advisable that the work to date be reviewed and the plans for the next cycle be revised or adapted. Note that the duration of a cycle can be anything from a few weeks through to many months. The key point is that plans should be revised or adapted to take into account the lessons learned or issues raised by water accounting and parallel water auditing activities. Another benefit of this incremental approach is it meshes well with social and institutional learning[32].

3.3.2 Identify and (re-)prioritise biophysical issues and concerns

Water accounting and auditing programmes have to strike a balance between focusing on issues and concerns that, in some cases, may be quite localised, and gaining a robust understanding of the broader biophysical characteristics and context of the specified domain. An obvious advantage of focusing on priority issues and concerns is that key stakeholders are more likely to engage actively with the programme; to share information with the implementation team; and, to feel they have ownership of and have confidence in the outputs. Flexibility is also desirable and, as such, the list of priority issues and concerns will, in most cases, be revised as more information becomes available and, possibly, as stakeholders are influenced by this new information.

Focus group discussions, key informant interviews and field or site visits with key stakeholders are a good place to start when identifying and prioritising issues and concerns. Reviews of relevant information on the web and in the media can also be helpful. There are some issues and concerns, however, that may not arise either because: 1) Stakeholders are not convinced that they are important (e.g. impacts of climate change or pollution within or downstream of specified domains; and 2) They are not currently apparent in the specified domains but, according to specialists, there is a significant risk they may become apparent at some time in the future. These concerns should be raised by the water accounting implementation team and discussed during stakeholder meetings.

[32] This approach is also based on learning alliance concepts and cycles of action research. For more information see Chapter 3.8 in Butterworth *et al.*, 2011.

At the same time as issues and concerns are discussed, it is advisable to start: 1) Linking issues and concerns with observed or perceived causes (both biophysical and societal); and 2) Documenting opportunities for addressing issues and concerns that are already being used or that could be considered in the future.

Throughout this process it is advisable that information be documented relating to the nature of the issues and concerns; the locations where they occur; the water users or uses that are most affected; the frequency and duration of occurrence; and, whether or not there is evidence indicating that issues and concerns are worsening.

3.3.3 Develop and update perceptual models

Information obtained during the identification and mapping of issues and concerns and from earlier cycles of water accounting and auditing can be consolidated and summarised in one or more perceptual models[33]. Typically, these will be in the form of a cause and effect diagram or a problem tree. The aim is to produce a graphical representation of, for example, the dominant biophysical and societal processes that influence water flows, fluxes and stocks (in space and time) and, for example, delivery of water services to different water users. One of the main benefits of developing perceptual models is that it encourages those involved to think carefully about the underlying causes of water-related problems in specified domains.

In most cases, a small group of specialists and key stakeholders will develop or update the perceptual models. As a result, the models will reflect the perceptions, knowledge and experience of this group. However, the perceptual models can also be shared, discussed and modified following a broader consultative process (e.g. during a multi-stakeholder platform meeting).

3.3.4 Re-specify and delineate biophysical domains of interest

In most cases, geographical location and administrative boundaries specified during the inception period of a water accounting and auditing programmes will remain unchanged. Similarly the boundaries of large irrigation schemes, once specified, will not be modified. In contrast, hydrological boundaries and units are often re-specified (e.g. catchments or aquifers) as part of multi-scalar analysis and making best use of available empirical information when, for example, calibrating and validating hydrological models or analysing return flows[34].

Commercial and open-source software can be used when delineating catchments of different sizes with outlets at different positions along drainage lines. In addition to software, delineation requires a digital elevation model (DEM). DEMs are grid-based GIS coverage that represent elevation. Typically DEMs are available with 10 m, 30 m, 90 m and larger cell sizes. The smaller the cell sizes, the more detailed and accurate the topographic information will be. However, if small hydrological units are delineated

[33] Perceptual models are qualitative descriptions of the biophysical processes. Perceptual models are also referred to as conceptual models or mind maps. If relevant, perceptual models should take into account the influence that infrastructure and engineering may be having on water flows, fluxes and stocks (in space and time).

[34] Return flows are defined as that part of a diverted flow that is not consumptively used and returned to its original source or another body of water. For example, drainage water from irrigated farmlands that re-enters the water system to be used further downstream is a return flow.

and high-resolution elevation data are used, the processing time of, for example, modelling runs at the large catchment or river basin scale will increase substantially.

When specifying and delineating biophysical domains, it is also important to identify and map water users and uses located outside the specified domains but, even so, whose water sources or services originate in or upstream of the specified domains. These water users could be urban water users who rely on bulk water transfers from the specified domains or downstream aquatic ecosystems that rely on environmental flows (see Box 3.3).

3.3.5 Update the communication strategy

It is advisable to make regular updates to the strategy used for communication within the water accounting and auditing implementation team, with and between stakeholders at different institutional levels and more broadly with the media and public. More guidance on communication strategies can be found in Section 6.

BOX 3.2

Surface and groundwater interactions

Surface and groundwater interactions should be considered during activities that include:

- River basin and watershed management,
- Water services delivery for agricultural, urban, domestic and other uses,
- Estimating and managing return flows,
- Conjunctive use of surface and ground water,
- Assessing impact of groundwater overdraft on natural contaminants (e.g. arsenic, fluoride),
- Wetland management and restoration,
- Monitoring and regulating dispersed and non-dispersed pollution,
- Estimating and managing environmental flows.

Source: GWP, 2013

BOX 3.3

Maintenance of aquatic ecosystem goods and services

Aquatic ecosystems depend on the maintenance of groundwater levels and flow regimes in river systems. Increasingly environmental requirements are identified and included in water accounting programmes. Even so, the tendency in many countries is to ignore environmental requirements or to regard aquatic ecosystems as residual claimants on water. The conceptual framework proposed here is that the environment should not be considered as a competitor for water with other uses. Instead, the preservation of environmental functions is a pre-condition for maintaining supplies for other purposes. While preserving the environmental function of water systems is a priority, maintaining the necessary levels of environmental flows often involve detailed negotiation that has to take into account the political and social acceptability of agreements that are reached. Furthermore, since agricultural landscapes also perform environmental functions, often the boundaries between environmental water requirements and agricultural water demand are not clear. More positively, water accounting and more specifically, modelling and scenario analysis can be used to investigate the benefits and potential trade-offs associated with re-establishing and maintaining environmental flows in specified domains and, if relevant, downstream of these domains.

Source: FAO, 2012

3.3.6 Availability of funds and other resources

Funds: At the beginning of each iterative cycle of water accounting and auditing, it is advisable to check that available funds match water accounting and auditing commitments and levels of ambition.

Specialist skills and experience: Typically water accounting requires specialist skills in the following disciplines hydrology, hydro-chemistry, hydraulics, irrigation engineering, agriculture and other land use systems, statistics, mapping and spatial analysis, modelling and information management. The mix of disciplines will, of course, vary with the issues and concerns in the specified domains. However, in most cases, it is not necessary to seek the services of a large number of specialists. Rather the challenge is to seek out experienced 'individuals' who are able provide a range of specialist inputs and, ideally, who have an aptitude for interacting and engaging with stakeholders and non-specialists.

To be effective, water accounting (and auditing) programmes need implementation teams that are well managed and organized. However, these teams are often only as good as the 'weakest link in the chain'. Experience has shown that the weakest link is often

BOX 3.4

Mini-hydrology 101

Some hydrological basics that are often overlooked or ignored:

- **Water is a renewable resource**. Although highly variable is space and time, rainfall can be relied upon to replenish aquifers, rivers and reservoirs.
- **Water is in an almost continuous state of flux.** Constantly moving and changing water phases through processes that include evaporation, condensation, precipitation, infiltration, percolation and runoff.
- **Flow in porous media, such as soil, is proportional to the pressure gradient and the media's hydraulic conductivity (Darcy's Law).** For a given level of soil water content (or degree of saturation), hydraulic conductivity increases by several orders of magnitude going from clay to silty clay loam to sand.
- **Hydrological systems are interconnected.** Changes in land and water management in one part of a hydrological system may have significant impacts elsewhere in the system.
- **Water balances are based on the law of conservation of mass.** Water is not created or destroyed in any of the natural processes of the hydrological cycle. So water is never really lost from the hydrological cycle.
- **Distinctions between consumptive and non-consumptive water uses are important.** A consequence of a consumptive water use is that, for a specified domain, re-use or recycling of water is not an option.
- **A significant proportion of urban water use is non-consumptive.** In some cases, this non-consumed water returns to the environment (with or without treatment) and is reused locally or downstream.

in hydrology. Put simply, for water accounting to produce reliable and robust outputs, a sound understanding is required of physical processes and mechanisms that govern the flow, fluxes and stocks in both pristine and heavily-engineered catchments (see Box 3.4). In addition, the importance of hands-on training cannot be overestimated in for example, the use GIS software and good data processing and management practices.

Hardware that may be needed includes: GPS sets (or GPS-enabled smart phones), well dippers, water quality text kits, tape measures and/or measuring staffs, devices to measure water flow (e.g. clamp-on ultrasonic flow meters), cameras, remote-controlled drones (especially if GPS-enabled), laptop or tablet computers, surveying equipment (e.g. total stations).

Software that may be needed: GIS, modelling, spreadsheets or statistics, cloud-based data storage, teleconferencing. Note: open-source software is increasingly available that can be used during water accounting (this includes well-supported open-source GIS and modelling software).

3.4 BIOPHYSICAL INFORMATION ACQUISITION AND MANAGEMENT

3.4.1 Information needs and availability assessment for the current cycle

Rather than trying to acquire all the available biophysical information, it is better to take a targeted approach based on regularly updated needs assessments. The aim of such assessments is to differentiate between information that is really needed, information that might be useful and information that is of no relevance at all. Ideally these assessments should be repeated, or at least be updated, at the beginning of each subsequent cycle of water accounting (and water auditing).

FIGURE 3.2
Get the information you can

Photo: Walt Stoneburner

In most cases, information needs and availability assessments are crosscutting activities that consider information needed for water accounting and auditing. Water accounting and auditing both need quantitative and qualitative information. However, there are some fundamental differences between water accounting and auditing in terms of the data needed and the ways in which it is analysed:

- Disciplines such as hydrology, agronomy, and soil science are grounded in well-understood universal principles (rooted in the laws of physics) that can be used, for example, when estimating or simulating water flows in natural or disturbed landscapes. In contrast, there is no agreement among social scientists with regard to the 'laws' of human behaviour (Merrey and Cook, 2012).
- Hydrologists can, for example, use secondary data from hydrometric networks to model and characterise catchments and basins with This is more difficult for social scientists because many of the societal characteristics of interest

(e.g. influence, understanding, attitude, etc.) are difficult to measure, predict or simulate with confidence[35].

- Given the above, water accounting tends to rely more on secondary information that is quantitative and empirical rather than qualitative (e.g. expert opinion) even though the latter is often important and informative. In contrast, often water auditing has to rely more on primary information that is qualitative while making good use of any secondary qualitative and quantitative information that is relevant to the specified domains.

Some other points that are relevant to biophysical information needs assessments include:

- **Biophysical information needs assessment**. This assessment can be guided by: 1) Issues, concerns and opportunities that have been identified and prioritised by stakeholders; 2) Findings from other studies or earlier rounds of water accounting and auditing; 3) Advice from well-informed specialists or experts; 4) Information requirements of the methods of analysis and modelling that you expect to use; and, 5) Perceptual models of, for example, dominant hydrological processes or bulk water-supply networks. This needs assessment should also be guided by, or take account of, relevant metadata that may be required and the spatial and temporal scales that are of most interest.
- **Information sources assessment.** In general stakeholders, have a good appreciation of the available secondary information and who holds this information, whether or not it is easily accessible, and whether or not it is reliable (i.e. can be trusted). It is often the case that secondary information exists but for one reason of another it is not easy to access. If some holders of information are unwilling to share their data, it may be necessary to seek out alternative sources and, in extreme circumstances, select different approaches to water accounting. More positively, the number of open access global databases is increasing. Table 3.1 lists some FAO and partners' web sites where biophysical information can be found and downloaded at no charge. Although the scale of available information tends to be relatively rough, the FAO and other open-access databases are often excellent sources of information on water accounting.
- **Need for primary information collection.** Having completed the assessments listed above, the conclusion may be that primary information may be needed to update, fill gaps and/or ground truth the information required for setting up and running the model(s). If this is the case, a plan should be prepared, field teams trained and mobilised and the additional information should be collected;
- **Planned or actual practices.** Often the readily available biophysical information relates to planned activities or management rules, for example, in relation to the management of an irrigation scheme. Actual practices are often very different and not documented. In terms of policies, laws, regulations and rights, a distinction is made between de jure information that refers to the formal rules found in policy and legal documents and de facto information that refers to what happened in practice (UNDP, 2009).

More guidance on information management can be found in Section 5.

[35] Note that interesting research techniques are being used to analyse and model societal information (See Section 5).

TABLE 3 1
Examples of global programmes for data harmonization, generation and sharing

Water scarcity status (in specified domain	Types of stakeholder engagement	Types of water user group and/or stakeholder platform
AQUASTAT (FAO)	Global information system on water resources, water uses and agricoltural management, with an emphasis on countries in Africa,Latin America and Caribbean	www.fao.org/nr/aquastat
FAOSTAT	The largest global source of agricultural data, with over one million time series	faostat.fao.org
Geonetwork	FAO's geospatial clearing house is a standardized and decentralized catalogue giving wide access to geo-referenced data, cartographic products and their metadata	www.fao.org/geonetwork/srv/en/main.home
GAEZ	Inventory of the world's agricultural resources organized around the theme areas of: land and water resources; agro-climatic resources; agricultural suitability and potential yields; and actual yields and production	www.fao.org/nr/gaez/en/
AQUAMAPS (FAO)	FAO global online spatial database on water and agriculture	www.fao.org/nr/water/aquamaps/
GEOSS	Earth geospatial data network	www.earthobservations.org/
FAO Soil Portal	Fao platform for soil information	www.fao.org/soils-portal/en/
GLCN	Global alliance for standard multi-porposeland cover data production	www.glcn.org
LADA	Land degradation assessment in drylands	www.fao.org/nr/lada
UN-Water	Fostering information-sharing and knowledge-building across all United Nations agencies and external partners dealing with freshwater management	www.unwater.org/ flashindex.html
Water Accounting Plus	Platform for hosting and sharing 'Water Accounting Plus (WA+)' approach developed by UNESCO-IHE, IWM and FAO. The data sources page provides links to public domain datasets.	www.wateraccounting.org
Wocat	World overview of conservation approaches and technologies	www.wocat.net

Source: FAO, 2011a

3.4.2 Information acquisition, processing and quality control

Information acquisition, processing and quality control take time, skill and patience. There are often delays in acquiring secondary information and reconciling secondary and primary information can be a challenge. The key steps are to: 1) Develop a strategy for acquiring and managing biophysical and societal information (guidance on this can be found in Section 3.5.3); and 2) Ensure that personnel responsible for this work are well motivated and have had the necessary training. Considerations to be taken into account while implementing this strategy include:

- **Information acceptability:** Appropriate criteria used for assessing the acceptability and usefulness of both primary and secondary information (see Box 3.5).
- **Information quality control:** It is important that all information used in water accounting is subjected to some level of quality control. For more information on quality control procedures see Section 5.

BOX 3.5

Criteria for assessing the acceptability of information

Criteria for assessing information acceptability include:

Accuracy: The measure of how close a result is to the true value.

Precision: The level of agreement between multiple measurements of the same characteristic.

Representativeness: The degree to which information collected accurately represents the population of interest.

Bias: The difference between an observed value and the "true" value of the parameter being measured

Comparability: The similarity of information from different sources included within individual or multiple datasets (e.g. level of agreement between remotely-sensed and terrestrial data)

Gappiness: The frequency and duration of information gaps in, for example, rainfall records.

- **Structured information acquisition and storage:** One option for structuring information acquisition is to use the Resources, Infrastructure, Demand/Access (RIDA) framework (see Section 3.5.3).
- **Blending data from different sources:** Increasingly information acquisition for water accounting involves blending information from a range of different sources (e.g. from remote sensing, hydrometric networks and citizen scientists). This requires both good computer skills and understanding of the subject matter.
- **Multiple independent sources of information:** When acquiring information, it is advisable to acquire information from a range of independent sources. The aim is to triangulate and/or corroborate interesting findings and, in so doing, increase (or possibly decrease) confidence in these findings.
- **Scales of interest:** As a general rule, it is best to acquire empirical information at the scale at which analysis and modelling is planned and, thereby, avoid the complexities and inherent uncertainties of upscaling or downscaling.
- **Real time:** Ideally, primary and secondary information is processed, blended and

BOX 3.6

Don't Forget the Metadata

Metadata is the additional information that you need to make sense of secondary data (or information) that you might download from an online database. Metadata includes:

- Definitions or explanations of acronyms or abbreviations used (e.g. attribute tables);
- Information on how and when the data were collected (e.g. methodologies, sampling frames etc.);
- Information on the units used;
- Information on when the data were collected and by whom;
- Information on whether the data have been processed and quality-controlled;
- Information on whether the data are empirical or simulated.

Source: EPA, 2008

quality controlled in real time (i.e. as it is acquired). This makes it possible for issues to be identified and, if relevant, for alternative sources of information to be found or changes to be made to the process of acquiring primary information.

- **Knowing when to stop:** Clearly for water accounting outputs to stand up to scrutiny and gain the confidence of stakeholders, sufficient primary and secondary information must be acquired, processed and quality controlled by the end of the water accounting programme. However, the temptation is to collect and process far more information than is needed and, as result, reduce the time and other resources available for other steps in the water accounting process.

3.4.3 Storage and sharing of data

Information and associated metadata need to be stored and shared in easily accessible forms and formats, for example, in a structured information base that stores the information on the cloud. Internet-based commercially available systems for storing and sharing digitised information such as Dropbox or Google Drive, are easy to use and an alternative to, for example, creating more complex management information systems. In all cases, however, disciplined, structured, management of information is needed to ensure that raw, processed and simulated information is not unwittingly mixed together.

As is the case in other aspects of water accounting, it is advisable to consider different options and develop a strategy for storing and sharing information. The focus needs to be on the users of the system, their IT preferences and their willingness to share information, rather than on technical aspects.

3.5 TARGETED BIOPHYSICAL ASSESSMENTS

3.5.1 Aims of targeted biophysical assessments

The aims of targeted biophysical assessments include: investigating the underlying causes of issues and concerns highlighted by stakeholders; answering specific questions; checking findings from earlier studies; developing a good understanding of the current status and trends in water supply and demand in the specified domains. The biophysical understanding gained should be sufficient to contextualise, underpin and assist the interpretation of outputs from the targeted assessments and the detailed multi-scalar biophysical analysis and modelling that follows in the next phase of water accounting.

Another benefit of targeted assessments is they often unearth problems with the biophysical data that were missed by earlier quality control procedures. Triangulation of findings from the assessments, with findings or outputs from relevant earlier or ongoing programmes, also helps indicate possible problems with the data and, more positively, identify real differences between the results of the targeted assessments and other studies (should these exist).

3.5.2 Analytical approach of biophysical assessments

Many different analytical approaches, methods and tools are used as part of targeted assessments. Selection will depend on: the focus of the assessment; the data that have been collected; and the concerns or issues under investigation. The capacity of those responsible for analysing the data is also a factor. In most cases, a combination of approaches, methods and tools will be used. In broad terms, the main approaches used include:

- **Summary statistics:** Statistical analyses are essential tools for describing data and evaluating relationships among different types of data and communicating results to stakeholders and the wider public Microsoft Excel and other spreadsheet programs can be used to calculating simple statistics. In addition, you can manipulate data sets by creating pivot tables. These and some other summary statistics are described in Box 3.7.
- **Spatial analysis:** Geographic information systems (GIS) are used to support data analysis by creating maps and displaying information on these maps. GIS

BOX 3.7

Commonly used summary statistics

Measures of range: Identify the span of the data from low to high

- **Minimum:** The lowest data value recorded during the period of record
- **Maximum:** The highest data value recorded during the period of record

Measures of central tendency: Identify the general centre of a dataset.

- **Mean:** The sum of all data values divided by the sample size (number of samples). Strongly influenced by outlier samples (i.e. samples of extreme highs or lows); one outlier sample can shift the mean significantly higher or lower.
- **Median (P_{50}):** The 50^{th} percentile data point; the central value of the dataset when ranked in order of magnitude. The median is more resistant to outliers than the mean and is only minimally affected by individual observations.

Measures of spread: Measure the variability of the dataset.

- **Sample variance (s^2 and its square root, standard deviation(s):** The most common measures of the spread (dispersion) of a set of data. These statistics are computed using the squares of the difference between each data value and the mean, and therefore outliers influence their magnitudes dramatically. In datasets with major outliers, the variance and standard deviation might suggest a much greater spread than exists for most of the data.
- **Interquartile range (IQR):** The difference between the 25th and 75th percentile of the data. Because the IQR measures the range of the central 50 percent of the data and is not influenced by the 25 percent on either end, it is less sensitive to extremes or outliers than the sample variance and standard deviation.

Measures of skewness: Measures whether a dataset is asymmetric around the mean or median and suggests how far the distribution of the data differs from a normal distribution.

- **Coefficient of skewness (g):** Most commonly used measure of skewness. Influenced by the presence of outliers because it is calculated using the mean and standard deviation.
- **Quartile skew coefficient (qs):** Measures the difference in distances of the upper and lower quartiles (upper and lower 25 percent of data) from the median. More resistant to outliers because, like the IQR, uses the central 50 percent of the data.

Souce: EPA, 2008

is also used to investigate and analyse the factors and mechanisms that influence spatialvariability in, for example, runoff, land use and patterns of water demand and use.

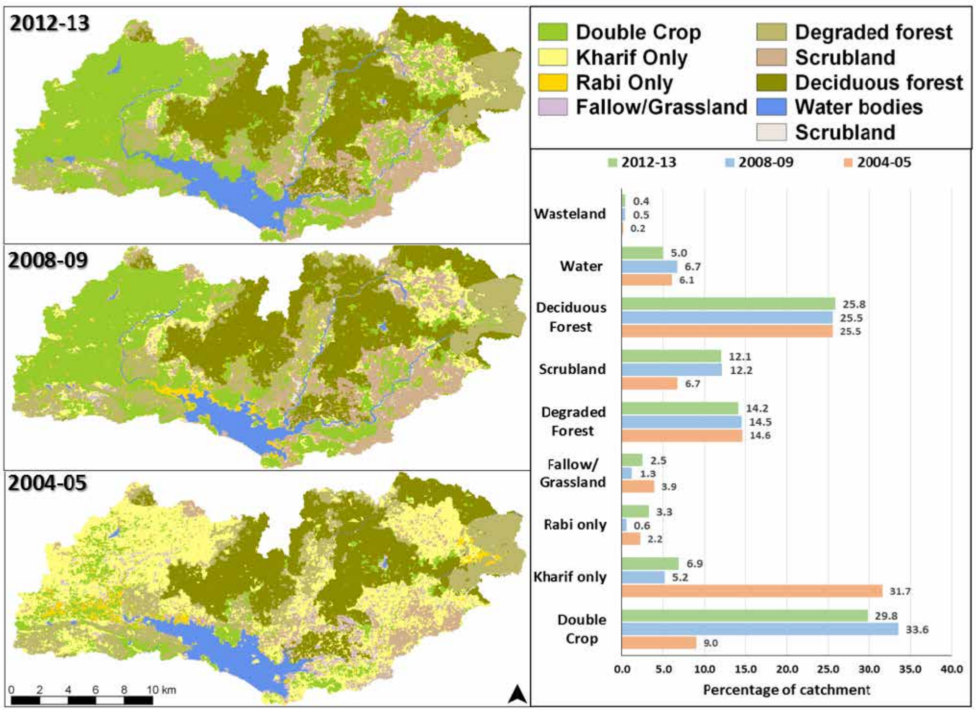
In the past, GIS software was expensive and used primarily by GIS specialists. In recent years, however, there has been a dramatic turnabout. Open-source GIS software is much improved, well supported (e.g. by online tutorials and chat rooms) and downloadable at no charge. In addition, many have become accustomed to using mapping applications on a regular basis (e.g. Google Maps or Google Earth on PCs or smartphones and satellite navigation systems in vehicles).

As a result, many more people are willing and able to use standard GIS applications (e.g. changing the features that are displayed on a map) and many specialists (e.g. hydrologists, engineers, etc.) have learned to use advanced GIS applications.

In a typical water accounting programme, it is now possible for all members of the implementation team and many stakeholders to use GIS to create, interrogate and interpret maps. Ideally there should be at least one person on the team who is capable of, for example, blending spatial data from different sources, using advanced spatial analysis and setting up and using GIS-based models.

- **Temporal analysis.** Many of the characteristics of a water supply system vary over time (see Figure 3.3). This variation can be cyclical (e.g. seasonal weather systems), an upward or downward trend (e.g. in groundwater extraction) or best represented as a probability distribution (e.g. the probability of extreme floods or droughts)
- **Trend analysis** using linear regression, multiple regression and time series analysis are all standard techniques that are used in temporal analysis. However, the

FIGURE 3.3
An example of both temporal and spatial analysis of land use change



Source: James et al., 2015

challenges are often to: 1) Assess whether important biophysical characteristics (e.g. rainfall, frequency of extreme rainfall events) are really changing over time or whether the trends observed are within natural variability; and 2) Identify the underlying causes given that one event following another does not mean that the first event is the cause of the second event.

3.5.3 Organizing data and information: the RIDA framework

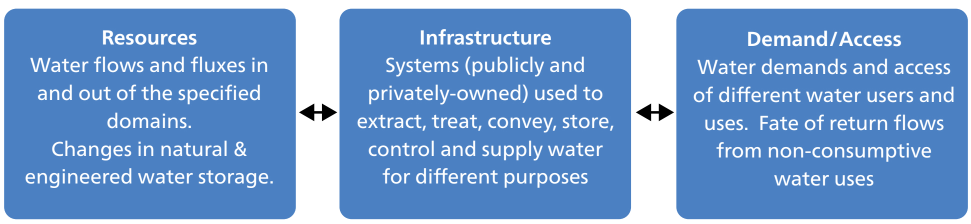
The RIDA framework can be used to organize and structure the collection, analysis, and presentation of data and information. The concept is very simple (see Figure 3.4). A water supply or delivery system can be divided into three inter-linked components (i.e. resources, infrastructure, demand or access). Demand for and access to water are lumped together in the RIDA framework because they are considered to be 'two sides of the same coin' in that, from a practical standpoint, demand for water cannot be separated from the ability of users to access and make use of water.

The rationale for the RIDA framework is as follows: when the demands of all water users and uses are not satisfied, biophysical assessments (organized around the RIDA framework) can be used to investigate whether underlying causes are: resource-related (e.g. falling groundwater levels) or infrastructure-related (e.g. a poorly maintained pipe network). As will be discussed in Section 4, in such assessments, it is advisable to consider whether the underlying causes are related to demand and access issues (e.g. poor governance, lack of water rights or inability to exercise a water right).

The RIDA framework can also be used to organize and group layers in a GIS information base and subsequent analysis of these layers[36]. When used to frame multiscalar analyses, the RIDA framework helps identify, for example, return flows from irrigation schemes or urban areas. It is worth noting that, in terms of water accounting, the biophysical disciplines for studying 'resources' include hydrology and hydro-chemistry; for studying 'Infrastructure' include hydraulics and engineering; and, for studying 'Demand/Access' include agronomy and environmental sciences.

In terms of the practical relevance to water accounting: the RIDA framework can be used to organize and structure checklists of questions (see Box 3.8) and be used as a basis for analysing water flows across the RIDA interfaces (e.g. from resources into infrastructure) (see Table 3.2).

FIGURE 3.4
RIDA framework



[36] The FAO water accounting study in Malta used the RIDA framework to structure spatial analysis and the final report. See. Sapiano *et al.* (2006) ftp://ftp.fao.org/docrep/fao/009/a0994e/a0994e.pdf

BOX 3.8

Example of a typical checklist of water accounting (and auditing) questions

This list is not exhaustive and, in practice, it is expected that key stakeholders would play an active role in developing such a list for a specified domain.

Resources:

- What are the main sources of water that are exploited for different uses?
- Are there indications of unsustainable use of water sources? If yes, have the causes been identified?
- Are there any localised or widespread conflicts over resources during dry seasons or droughts?
- Are unconventional water resources being exploited (e.g. treated wastewaters)?
- Are changes in land use/management impacting positively or negatively on resources
- What major institutions are involved in managing water resources? What are their roles and responsibilities? How effective are they?

Infrastructure:

- What main types of infrastructure are being used for uses that are different to what they were designed for?
- What is the functionality of this infrastructure, i.e. does it supply sufficient water of an acceptable quality when and where it is needed 365 days per year even during droughts?
- Who is responsible for operating, maintaining and financing infrastructure?
- Is water quality monitored? Are test results on water quality in the public domain?
- Are there plans for construction of new dams, well fields, or bulk water transfer systems?
- What is the perceived efficiency of the supply systems?
- Are supplies of water metered and regulated? Are there penalties for illegal connections or similar?

Demand/Access

- Is the demand of all water users and uses satisfied 365 days per year even during droughts?
- Do users have formal or informal rights to water?
- Is demand regulated or managed in any way? If yes, what are the formal or informal procedures?
- What are the key water related institutions relevant to the various water-user groups?
- What are the coping strategies of those who cannot reliably access public water services?
- What are the barriers to access that are experienced by different wateruser groups (e.g. social exclusions, high user fees, etc.

TABLE 3.2
Typical outputs from analysis of flows across RIDA interfaces

RIDA interfaces	Focus of water accounting
Resources – Infrastructure	**Extraction and return flow estimates:** Volume and quality of water in space and time entering into water supply infrastructure. Volume and quality of return flows to rivers or groundwater
Infrastructure-Demand	**Delivery estimates:** Volume and quality of water delivered at the point of supply to different water users in space and time. A measure of unaccounted for water can be based on difference between extraction and delivery estimates.
Demand-Access	**Water scarcity estimates:** The extent to which delivery of water meets the Demands of users (including the environment) in space and time.

3.5.4 Types of targeted biophysical assessments

The scope and scale of targeted assessments are often constrained by the availability of time, information and capacity. Therefore, some targeted assessments may focus on issues and concerns that are highlighted and prioritised by stakeholders. While others are likely to focus on gaining a better understanding of the biophysical processes and mechanisms that determine water flow and fluxes into, out of and within the specified domain(s) and changes of stocks (i.e. storages) of water within the domain(s). Note also that in heavily engineered catchments or basins the emphasis of targeted assessment is likely to be on hydraulics and engineering rather than, for example, hydrology.

When implementing targeted assessments, it is important to recognize that the aim is not to carry out detailed research. Instead the focus is on producing findings and outputs that are well supported by the qualitative and quantitative evidence that is available. It is notable also that assessments can also provide good opportunities for social and institutional learning at different institutional levels.

Typical targeted biophysical assessments include (note that this list is far from exhaustive):

- **Rainfall analysis** assesses the: 1) Variation in the magnitude, duration and intensity of rainfall events; 2) Inter-and intra-annual variability; and 3) Signals of climate change (e.g. changes in the frequency of extreme events, the intensity of rainfall and annual or seasonal rainfall totals).
- **Stream (or river) flow analysis** assesses: 1) Inter-and intra-annual variability in stream-flows; 2) Long-term trends in stream-flow; and 3) Reasons for any change in flow regimes.
- **Groundwater assessment** of the: 1) Groundwater potential; 2) Current levels of groundwater extraction; and 3) Trends in well construction (e.g. well type, depth, type and capacity of pump, etc.).
- **Land use and land management assessment** of the: 1) Main land uses and land management practices; 2) Trends in land use and land management; 3) Potential impact on the water balance components.
- **Water quality assessment** of the: 1) Types of pollution (and natural contaminants such as arsenic and fluoride) in the specified domain and areas in which indicators of water quality are above permissible limits and 2) Trends in water quality (in space and time).
- **Infrastructural assessment** of the: 1) Spatial distribution and capacities of water supply, storage and treatment infrastructure; 2) The condition and functionality of this infrastructure; and 3) The operating rules of this infrastructure.

- **Inter-basin transfer assessment:** of the: 1) Spatial distribution and capacities of bulk water supply systems that import or export water from the specified domain; 2) The condition of these systems; and 3) The operating rules that are used.
- **Drainage system assessment** of the: 1) Spatial distribution capacity and types of drainage system; 2) The condition of these systems; and 3) If relevant, the operating rules.
- **Irrigation system assessment** of the: 1) Spatial distribution and types of irrigated systems; 2) Irrigated area and irrigated cropping systems; and the 3) Condition of the system.
- **Environmental sustainability assessment** of the: 1) Demand and consumptive use of water by different users and uses (in space and time); and 2) The extent to which current levels of water use are sustainable.
- **Ecological assessment** of the: 1) Extent to which environmental flows are being maintained in time and space; and 2) Levels and trends in the biodiversity of aquatic ecosystems.

3.6 MULTI-SCALAR BIOPHYSICAL ANALYSIS AND MODELLING

3.6.1 Aims of multi-scalar biophysical analysis and modelling

The main aims of multi-scalar biophysical analysis and modelling include: 1) Producing robust quantitative estimates of water balance components (i.e. the water accounts) for the specified domains at different scales of analysis; 2) Using outputs from the targeted assessments and additional modelling-based analysis to investigate the underlying causes of issues and concerns in the specified domain; and 3) Furthering assess opportunities for addressing the issues and concerns of key stakeholders and others.

Additional aims of this phase are to integrate, combine and/or link outputs from the targeted assessments, additional analysis and modelling and other sources with a view to: 1) Ensuring that outputs from this phase are well-supported by qualitative and quantitative evidence; 2) Assessing the sensitivity of water balance components to different biophysical drivers; and 3) Taking account of variability and uncertainties in water balance estimates at different scales of analysis.

A word of caution: Before proceeding with this phase, a judgement should be made on whether or not adequate information and understanding has been acquired relating to the dominant biophysical characteristics, processes and interactions in the specified domain. It may also be a good time to double check that the implementation team has sufficient modelling capacity and competency[37]. If information, understanding or capacity are lacking, it may be best not to proceed with this phase. The obvious risk is that a lot of time and energy could be invested in multi-scalar biophysical analysis and modelling that ends up producing questionable outputs that may not stand up to scrutiny.

3.6.2 Analytical approach of biophysical analysis and modelling

Once the targeted assessments are nearing completion, the next challenge is to integrate, combine and or link the findings and outputs from these assessments and other sources

[37] Competency is best measured as the amount of formal training in modelling disciplines and the number of years of modelling experience working on water accounting type programmes.

in ways that address priority and issues and enables robust quantitative estimates to be made regarding water balance components (i.e. the water accounts) at different scales of analysis.

There are many ways to integrate outputs from the targeted assessments and others sources. In most cases, this involves specialists from the implementation team and key stakeholders, checking whether the new information is consistent with the perceptual models that were developed or revised, in earlier phases of the water accounting process. If the evidence indicates that it is needed, changes should be made to the perceptual models. One advantage of this approach is that it encourages dialogue between specialists working with the implementation team and key stakeholder organizations.

The other most common means of integrating findings is to use an appropriate model. Rather than developing a model from scratch, standard practice is to select and use an existing model. Guidance on this process can be found in Section 5.3. An important aspect of modelling is that model users have an appreciation of the limitations of the selected model and modelling in general. Catchments and basins, where there is very little overall understanding of dominant biophysical characteristics, processes and interactions and not much data available for calibration and validation of the model are not good candidates for modelling (After Shilling *et al*., 2005). More positively, the state of the art of hydrological, hydraulic and ecological modelling has advanced significantly in recent years and options are increasing for calibrating and validating models at scales of interest even in remote areas with poor hydrometric networks (see Section 5).

The rest of this section focuses on water balance analysis, fractional analysis and water efficiency and productivity estimation because these methodologies are integral parts of most water accounting programmes. In addition, water balance analysis and fractional analysis are used when estimating water balance components at different scales. In some cases, these methods are embedded within a selected model in other cases model outputs are used as input data.

3.6.3 Water balance analysis

What is water balance analysis?

In the natural environment, water is in almost constant motion and is able to change state from liquid to a solid or a gas under appropriate conditions. The Law of Conservation of Mass requires that, for a specified domain over a specified period of time, water inflows are equal to water outflows, plus or minus any change of storage.

Put another way, the volume of water entering a specified domain has to be in balance with the water leaving this domain after changes in water storage are taken into account. This balancing of water inflows and outflows can be described in a simple water balance equation:

$$P = Q_{NET} + ET \pm \Delta S$$

Where for a specified spatial domain and a specified time period: P is the volume of precipitation; Q_{NET} is net volume of outflow; ET is the volume of evapotranspiration and ΔS is the change in the volume of stored water. In the real world there is usually more than one type of inflow/outflow and water can be stored above and below ground (see Figure 3.5). The equation above can be expanded to represent each inflow, outflow and storage type as separate terms as follows:

$$\underbrace{(P + G_{IN})}_{\text{Inflows}} - \underbrace{(ET + Q_{OUT} + G_{OUT})}_{\text{Outflows}} = \underbrace{(\Delta S_{SSW} + \Delta S_{SW})}_{\text{Change in storage}}$$

By making various assumptions, we can simplify the water balance equation and, in so doing, reduce the amount of information needed for water balance analysis. For example, if we make the assumption that G_{IN} and G_{OUT} are negligible and that over a long period ΔS is also negligible, then the simple water balance equation can be written as follows:

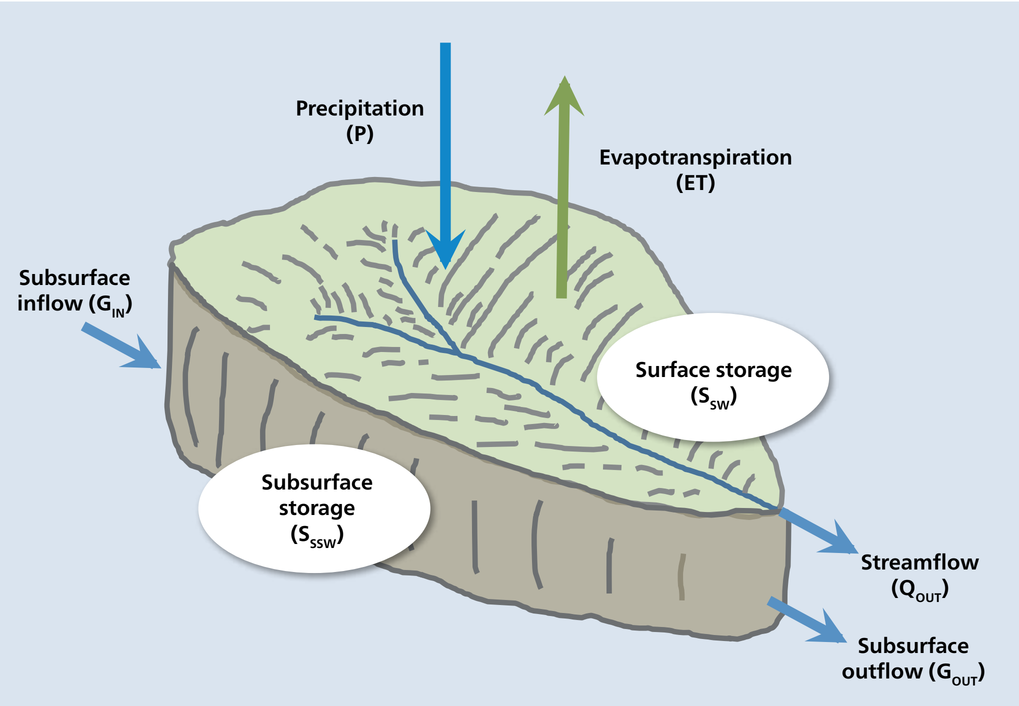
$$P = ET + Q_{OUT}$$

Except in very simple cases, the terms in the water balance equation cannot be estimated with total certainty. As a consequence, it is standard practice to include a residual term in the equation. The residual term includes and/or accounts for errors and uncertainties associated with estimation of water balance components. In some cases, the residual term can include other terms that cannot easily be measured or estimated (e.g. subsurface flows in and out of a specified domain). When a residual is included, the simple water balance equation becomes:

$$\underbrace{(P + G_{IN})}_{\text{Inflows}} - \underbrace{(ET + Q_{OUT} + G_{OUT})}_{\text{Outflows}} \pm \underbrace{(\Delta S_{SSW} + \Delta S_{SW})}_{\text{Change in storage}} = \textbf{Residual}$$

It is important to note that water balance analysis only considers: 1) Water entering or leaving a specified domain over a specified period of time; and 2) Changes in water

FIGURE 3.5
Water balance components of a small headwater cathment



stored within the boundaries of the specified domain during this specified time period. This means that water balance analysis is only interested in flows and fluxes of water that cross the boundaries of the specified domain and changes in stocks of water within the specified domain over the same specified time period.

What are the objectives of water balance analysis?

For a specified spatial domain (e.g. a field, an irrigation scheme, a catchment, an aquifer, a district, a river basin, etc.) and a specified time period (e.g. a day, a month, a year, a decade, etc.), water balance analysis can be used to:

- Identify and quantify water inflows and outflows,
- Identify and quantify changes in stocks of water (e.g. water stored in: reservoirs, water bodies, soil and groundwater),
- Quantify components of the water balance that are difficult to measure or even estimate (e.g. groundwater recharge) by assuming that they are the residual in the water balance equation,
- Assess the potential impacts on water balance components of, for example, changes in land use or management,
- Assess whether current levels of consumptive water use within the specified domain are sustainable or whether opportunities exist for rebalancing net inflows and outflows,

BOX 3.9

Some useful water balance analysis concepts and terminology

Runoff ratio: the fraction of precipitation that falls on a given domain over a specified time period that exits the domain as surface flow (i.e. Q_{OUT}/P)

Subsurface flow ratio: the fraction of precipitation that falls on a given domain over a specified time period that exits the domain as subsurface flow (i.e. G_{OUT}/P)

Water balance analysis (see Box 3.9) can also involve dividing specified domain(s) into smaller units based on specific biophysical characteristics (see Figure 3.6). For water balance analysis, the assumption is that these smaller computational units (often referred to as hydrological response units (HRUs) are homogeneous in terms of their hydrological response. The HRUs in Figure 3.6 were delineated on the basis of: land use or land cover, slope and soil type coverage.

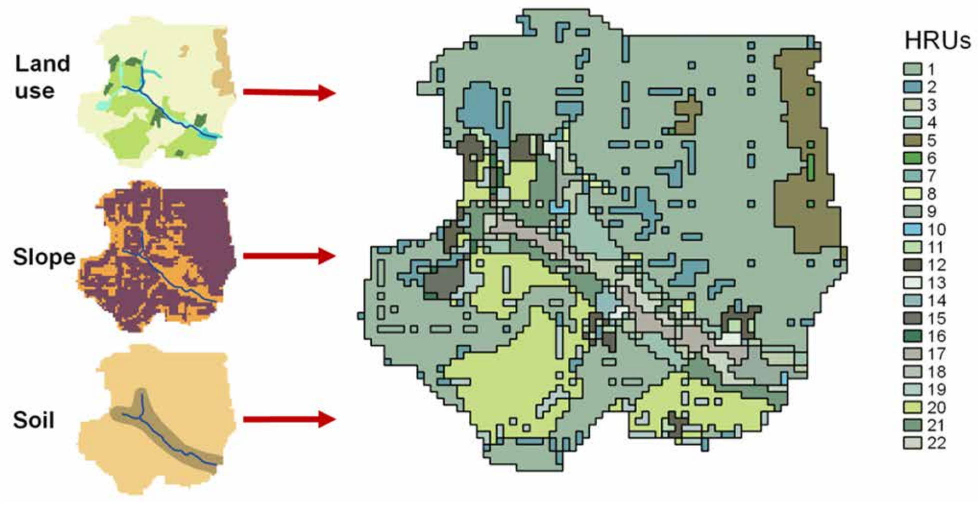
Water balance components

The following are typical components of water balance:

- ***Precipitation*** is a key component of water balance in terms of both absolute volumes of inflow and the variability of this inflow in space and time. Variability in precipitation at all temporal scales (e.g. hourly, daily, monthly, seasonal, annual, decadal and so on) has important implications for hydrology, water resources and the frequency or severity of extreme events (e.g. floods and droughts). Similarly, precipitation often exhibits high levels of spatial variability with regard to elevation and/or location relative to hills and mountains. To complicate matters further, the risk exists that climate change is influencing both absolute volumes and variability of precipitation including frequency of extreme events[38]. Obtaining reliable precipitation data for water balance analysis should be

[38] Royal Society (2010 and 2014) are interesting summaries of the science of climate change.

FIGURE 3.6
Example of delineated Hydrological Response Units in Figure 3.6

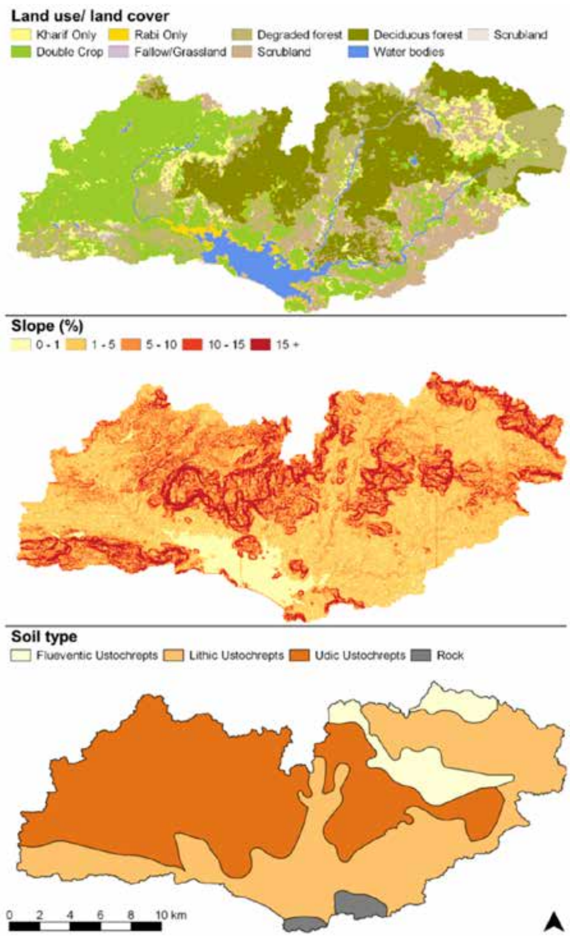


Source: James et al., 2015

relatively easy. However, the reality is that it is often a challenge, in part, because well-sited rain gauges provide information on rainfall at a point whereas, for water balance analysis, information is required on the total volume of precipitation falling on an area of interest over a given period. As a consequence, it is necessary to convert point rainfall measurements into spatially disaggregated estimates of rainfall. This can be done relatively easily using a GIS software environment by converting a digital data layer of the specified domain into a grid and using spatial analysis to produce weighted values of precipitation for each square of the grid. Alternatively, Thiessen polygons can be used to extrapolate rainfall between gauging sites. Uncertainties are introduced, however, when transforming and interpolating point rainfall measurements to areal volumes.

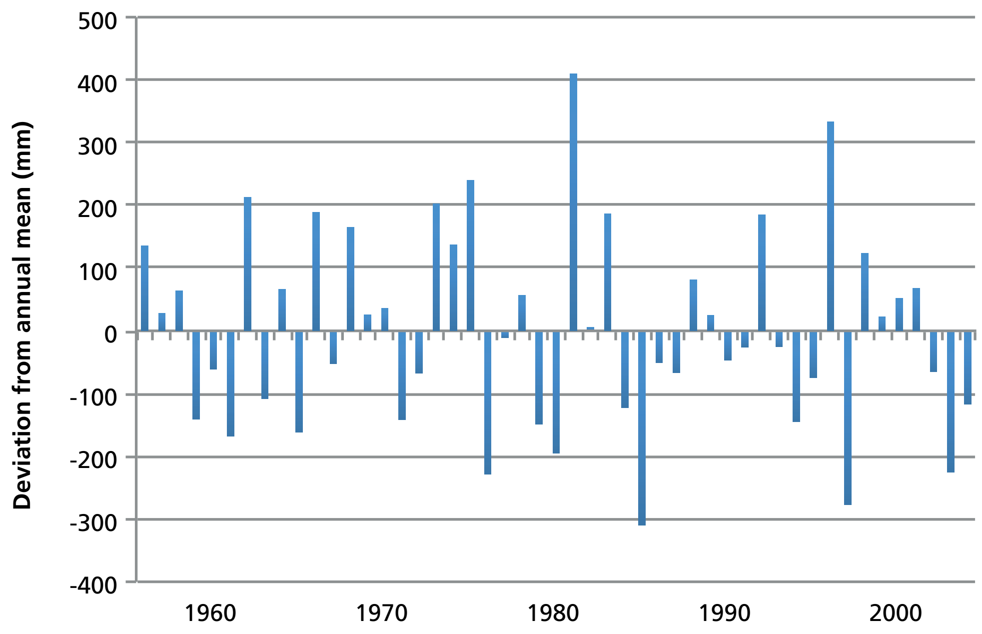
Increasingly, remotely-sensed rainfall data are being used as an input to water balance analysis. This trend is being driven in part by the poor state of hydrometric networks in many countries and the increasing availability of remotely sensed rainfall data on

FIGURE 3.7
Data used to delineate the Hydrological Response Units as shown in Figure 3.6



Source: James et al., 2015

FIGURE 3.8
Example of rainfall inter-annual variability



open-access web sites[39]. However remotely sensed rainfall is no solution because it is not always available at or for the scale, resolution or time period required. It is also notable that to date, many water professionals put more trust in rain gauge data than remotely sensed rainfall estimates.

- ***Evapotranspiration*** from land surfaces includes evapotranspiration from, for example: vegetation, bare soil, urban landscapes and water bodies such as lakes, rivers and canals. The rate of evapotranspiration from land surfaces is driven by meteorological factors, mediated by the characteristics of vegetation and soils, and constrained particularly by the amount of soil water accessible to the vegetation (see Figure 3.9). The primary meteorological controls on evaporation from a well-watered vegetated surface (also known as reference evapotranspiration[40]) are the amount of energy available (characterised mainly by net radiation), the dryness of the air (i.e. vapour pressure deficit), and the rate of movement of air across the surface (a function of wind speed and the roughness of the surface).

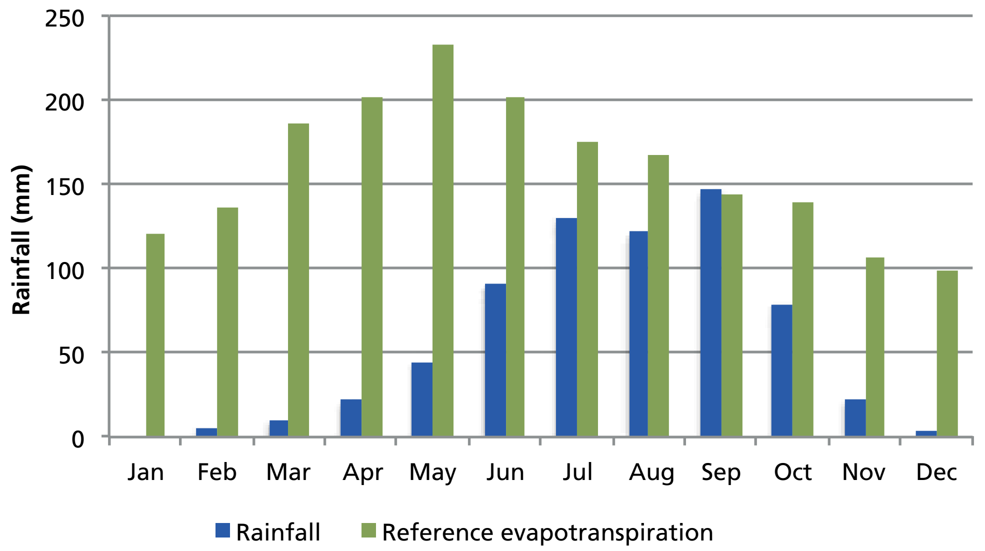
  The relative importance of different meteorological drivers, however, can vary geographically and seasonally. For example, in dry regions or seasons rates of evapotranspiration are determined primarily by energy availability and not constrained by the dryness of the atmosphere. So small changes in humidity are relatively unimportant. In contrast, in humid regions or seasons, atmospheric moisture content[41] is a major limitation to evapotranspiration. As a result, changes in humidity have a big influence on the rate of evapotranspiration in humid regions

[39] See, for example, the Tropical Rainfall Measuring Mission web site: http://trmm.gsfc.nasa.gov/ and the Climate Hazards Group InfraRed Precipitation with Station data: http://chg.geog.ucsb.edu/data/chirps/

[40] See Allen *et al*., 1998.

[41] To be more precise, it is the magnitude of the vapour pressure deficit (VPD) that is a limitation on rate of evapotranspiration. The VPD is the difference (deficit) between the amount of moisture in the air and how much moisture the air can hold when it is saturated.

FIGURE 3.9
Typical seasonal variation in mean reference evapotranspiration and rainfall in a semi-arid area



or seasons (Arnell and Liu, 2001). Although transpiration from plants through their stomata (i.e. the pores on leaves) is driven by energy, vapour pressure deficit and turbulence, plants exert a degree of control over transpiration, particularly when water is limiting. Stomata start to close as the vapour pressure deficit close to the leaf increases, temperature rises, or less water becomes available to the roots.

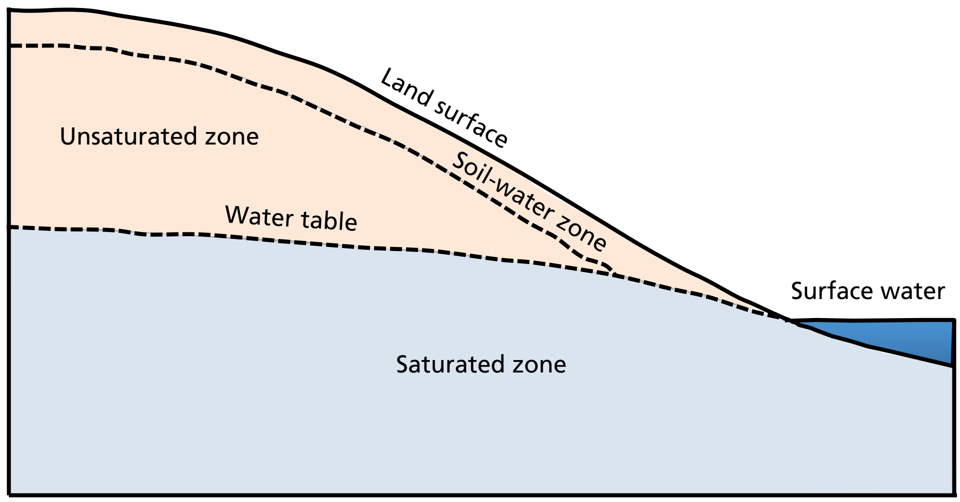
As yet, there are no reliable sensors for directly measuring actual evapotranspiration rates from land surfaces at a range of scales relevant to water balance analysis. As a consequence evapotranspiration has to be estimated using empirical relationships, algorithms and/or models that combine information on the drivers of and controls on rates of evapotranspiration. Use of this approach also requires information on land use and crop type. The net result of the above is that actual evapotranspiration is often estimated by, for example: 1) Estimating reference evapotranspiration and using empirical factors to estimate actual evapotranspiration (Allen *et al.*, 1998); and 2) Considering actual evapotranspiration to be the residual in the water balance equation – thereby being an output from water balance analysis rather than an input.

In recent years, increased attention has been given to estimating actual evapotranspiration using remotely sensed information. An example of this is the SEBAL approach developed by Bastiaanssen (2009), which is an image-processing model comprised of 25 computational steps that estimate actual (ETact) and potential evapotranspiration rates (ETpot) as well as other energy exchanges between land surfaces and the atmosphere. Section 5.2.5 and Box 5.7 provide further information on remote sensing based ETa assessments.

- ***Subsurface water*** that flows beneath the land surface occurs in two principal zones, the unsaturated zone and the saturated zone (see Figure 3.10). In the unsaturated zone, the voids[42] contain both air and water. Although a considerable amount of

42 Voids are, for example: the spaces between grains of gravel, sand, silt or clay; macropores created in soils or weathered material by roots or invertebrates; and/or fissures within rocks.

FIGURE 3.10
Cross-section showing saturated and unsaturated zones



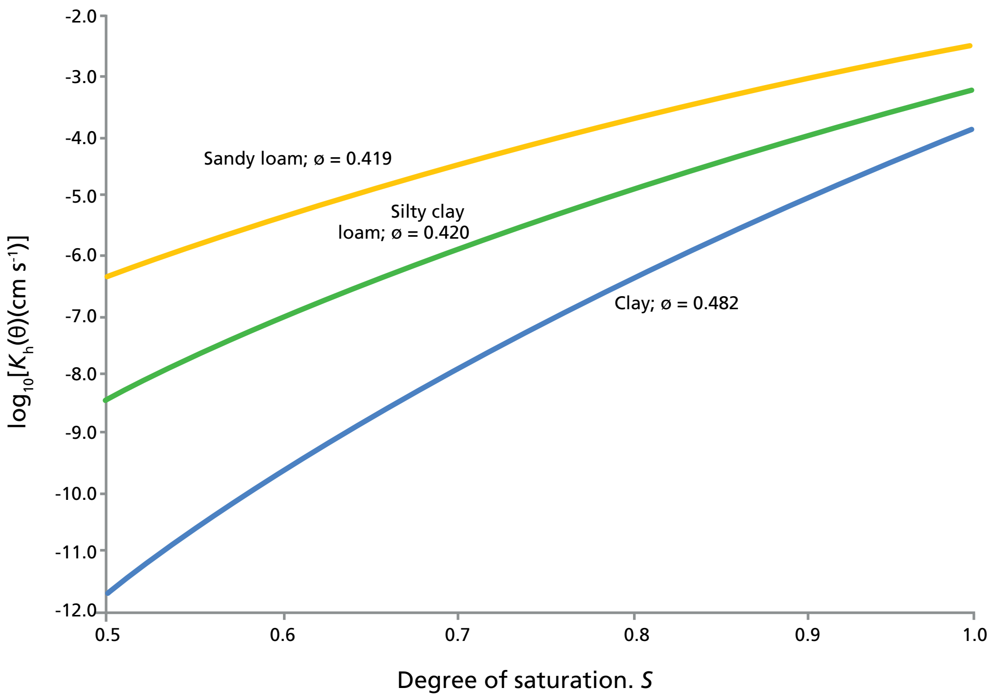
Source: USGS., 2013

water can be present in the unsaturated zone, flow of water in this zone tends to be slow and tortuous when the voids are not filled with water (USGS, 2013). However, if and when these voids are filled with water, hydraulic conductivity and rates of flow can increase by orders of magnitude (see Figure 3.11).

The upper part of the unsaturated zone is the soil-water zone. The physical properties and characteristics of soils along with the volumes of water stored in the soil are fundamentally important to agriculture and other land uses. In part because of the influence and controls soil properties and characteristics can exert on rates of actual evapotranspiration, access to nutrients and generation of runoff. Infiltration rates are particularly important because they influence rates of runoff. Infiltration rates of rainfall (or irrigation water) into soils are influenced by many soil-related factors that include: soil type, slope, condition of soil surface, presence of crop residues, hydraulic conductivity, presence of fissures or macropores, and antecedent soil moisture conditions. Information on water holding capacity (or storativity) of soils and the unsaturated and saturated zones is often needed when estimating (changes in) soil water storage. Water holding capacity is influenced by factors that include porosity, clay content, parent material and degree of weathering. A key point here is that water in the unsaturated zone is in a constant state of flux with direction and rate of movement controlled by the gradient of negative water potential and the hydraulic conductivity.

In terms of water balance analysis, it is often important to track and estimate: 1) The volume of water percolating through soils, beyond the root zone and through the remainder of the unsaturated zone and 2) Changes in soil and unsaturated zone water storage during the specified time period of interest. As drainage and soil water retention is rarely measured except during research studies, this information is usually obtained by using models (e.g. based on Richards equation see Box 3.10). It is useful to note that farmers often regard percolation of water beyond the root zone as a loss but, of course, this 'loss' can also be a major source of groundwater recharge. Failure to recognize this fact is a common cause of double counting in water balance analysis at the field and/or irrigation scheme scales. In contrast to the unsaturated zone, the voids of the saturated zone are completely filled with water. Water in the saturated zone is referred to as groundwater and the

FIGURE 3.11
Relationship between soil hydrologic conductivity and degree of saturation



Source: Dingman, 2002

upper surface of the saturated zone is called the water table (and sometimes *the phreatic surface*). Below the water table, the water pressure is high enough to allow water to flow into wells, thus permitting groundwater to be abstracted. The water table is continually adjusting to patterns and rates of abstraction and recharge both of which can be highly variable space and time. Highest rates of recharge can be expected whenever saturated conditions exist from the ground surface to the water table (e.g. under a pond, reservoir or stream). In such conditions, voids will fill, hydraulic conductivity will increase and the rate of recharge will be relatively high.

BOX 3.10
Richards equation

Richards equation combines Darcy's Law for vertical unsaturated flow with the conservation of mass. It is widely used as a basis for numerical modeling soil water flow by specifying appropriate boundary conditions, dividing the soil profile into very thin layers, and applying the equation to each later sequentially over small increments of time.

$$\partial\theta/\partial t = -\partial K_h(\theta)/\partial z + \partial/\partial z\ [K_h(\theta).\partial\psi(\theta)/\partial z]$$

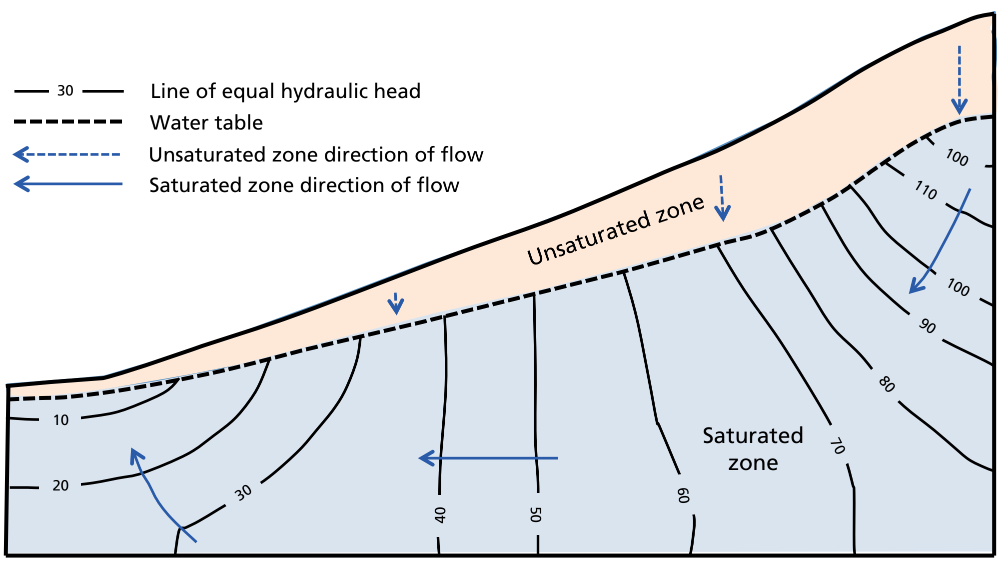
Expressed verbally, the time rate of change in volumetric soil moisture (θ) for a given thin layer of soil depends on the vertical rate of change of the hydraulic conductivity (itself a function of (θ) and the vertical rate of change of the product of (a) the hydraulic conductivity, and (b) the vertical rate of change of the pressure head, ψ (the matric suction gradient) the pressure head also being a function of θ. In this expression, z is taken to increase *downwards.*

The groundwater system as a whole is actually a three-dimensional flow field. As such, it is important to understand how the vertical components of groundwater movement affect the interaction of groundwater and surface water. Figure 3.12 shows a generalised vertical section of subsurface water flow. This shows that the flow of water is driven by gradients of water potential and the direction of flow is at right angles to lines (or three-dimensional surfaces) of equipotential or hydraulic head. Simplistically, the volume of groundwater discharge (flux) to and from surface-water bodies can be estimated for a known cross-section of aquifer as the product of the potential or hydraulic gradient and the hydraulic conductivity. In practice, it is better to select and use a groundwater model not least because the dynamics of three-dimensional water flows are complicated especially when interactions between surface water and groundwater are taken into account (see Figure 3.13).

- ***Runoff:*** A basic understanding of how rainfall (or snowmelt) is transformed into runoff and stream-flow is important in evaluating how human activities may alter the processes that generate runoff and stream-flow. A key point is that there are many possible processes or pathways by which a rainfall can reach a stream or river. Figure 3.14 is one perceptual model of what can happen on a hill slope between and during storms or rainfall events. In periods between storms, water storage in the soil and unsaturated zone gradually declines as a result of percolation and evapotranspiration from the land surface (Figure 3.14a). In addition, the level and gradient of water table may also decline slowly. Storage will usually be higher in the water table closer to the surface in the valley bottom riparian areas, partly because of downslope flow and partly because storage in these areas may be maintained by return flows from the stream. The antecedent conditions in the soil and unsaturated zone as well as the duration and intensity of a rainfall event will be important in determining the processes by which a catchment responds to rainfall (Figure 3.14b). Unless the stream is ephemeral, there will always be a response from precipitation directly onto the channel and the immediate riparian area. Some of the rainfall will be intercepted by the vegetation and evaporated

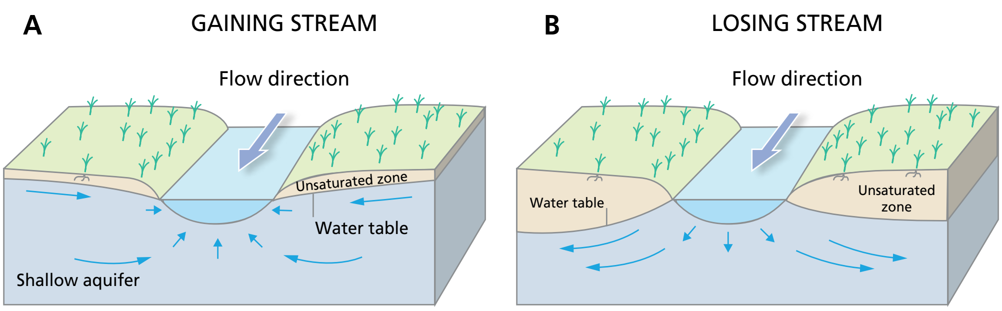
FIGURE 3.12

Generalised vertical section of subsurface water flow



Source: USGS, 2013

FIGURE 3.13
Ground/surface water interactions



Although it is quite a challenge, water accounting has to identify and, in some cases, quantify interactions between ground and surface water. An obvious interaction is the contribution that shallow groundwater makes to streamflow in the form of water from springs. In many cases, springs can be the only source of dry season streamflow.

In addition, streams interact more directly with shallow ground water in three basic ways: streams gain water from inflow of ground water through the streambed (e.g. the gaining stream in Figure A), they lose water to ground water by outflow through the streambed (e.g. the losing stream in Figure B), or they do both, gaining in some reaches and losing in other reaches.

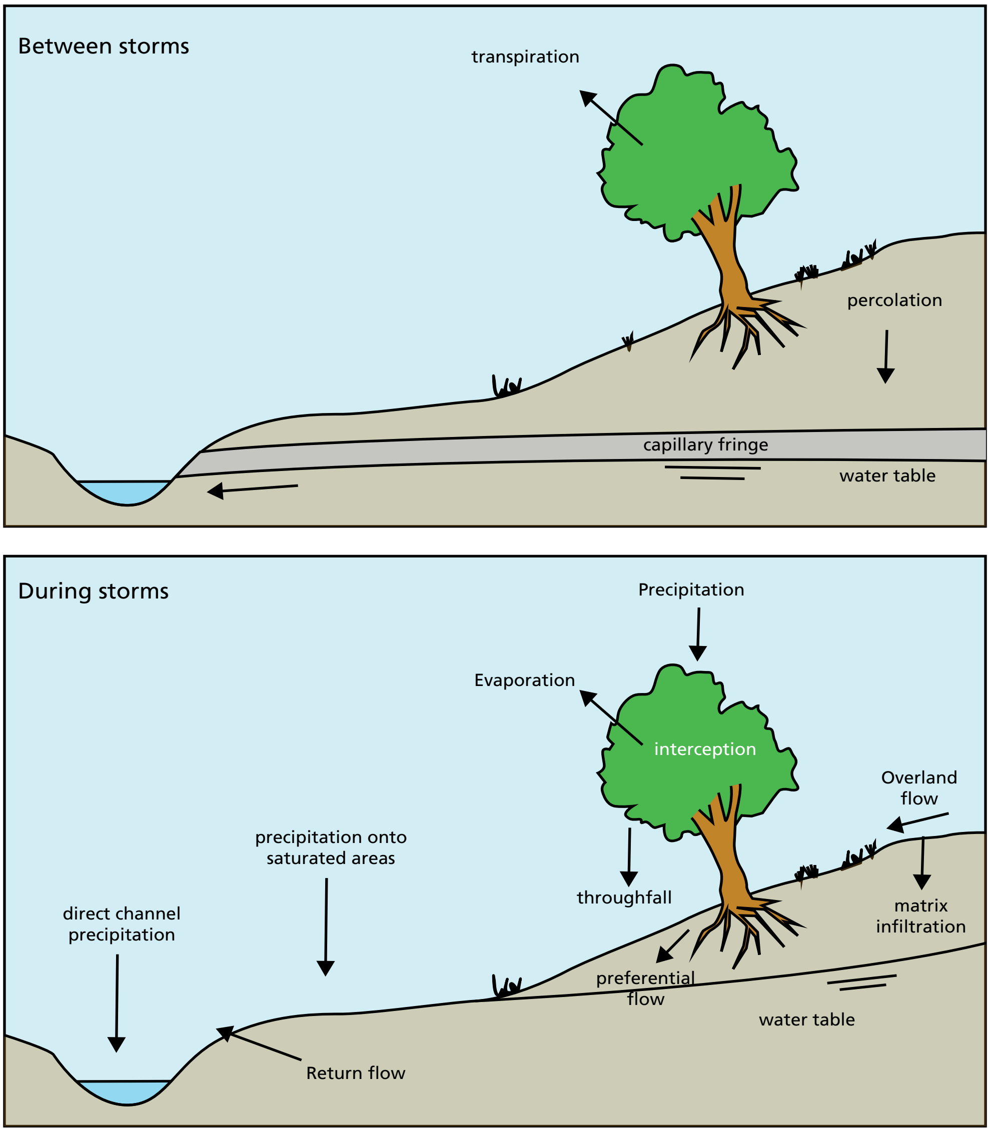
Source: USGS, 2013

directly back in to the atmosphere. The remainder will fall directly on the ground as *throughfall* or possibly run down the stems of the vegetation as stemflow. The rain that reaches the ground will start to infiltrate the soil surface except in areas that are impermeable (e.g. rock outcrops, roads, etc.). The rate of infiltration will depend on the rainfall intensity and infiltration capacity of the soil. Where the input rate exceeds the infiltration capacity, infiltration excess overland flow will be generated[43]. However, this is not the only mechanism by which overland flow can be generated. Figure 3.15 presents an additional four mechanisms.

Human activities can alter the physical processes that generate stream-flow in a variety of ways — removing or adding intercepting surfaces, such as vegetation and leaf litter, changing the 'infiltration capacity' of the soil (ability of soil to absorb water), changing the storage capacity of the soil, changing the transmission capacity of the soil (ability of the soil to allow water to move through it), changing the ability of vegetation to remove water from the soil and release it to the atmosphere, changing the density of small channels that collect surface flow, for example. Compacting soil is a common result of foot and vehicle traffic that reduces the ability of the soil to absorb, store, and transmit water. As less water enters the soil, more water runs off into channels, thereby increasing stream-flow over shorter time intervals than would occur in the absence of compaction. Sealing soil with concrete, asphalt, or buildings can prevent any water from entering the soil and causes almost all the rain to flow quickly to a stream (or drainage system). The amount or proportion of impervious (watertight) surfaces in a watershed is a common indicator of the degree to which runoff-generating processes have been altered. In addition, many watershed management activities will, in most cases, reduce overland flow, e.g. in-field water harvesting and soil and water conservation; ploughing and planting crops along contours; afforestationand agro-forestry and many improved rainfed-farming practices.

[43] This process is often referred to as Hortonian flow.

FIGURE 3.14
Hill slope processes involved between and during storms



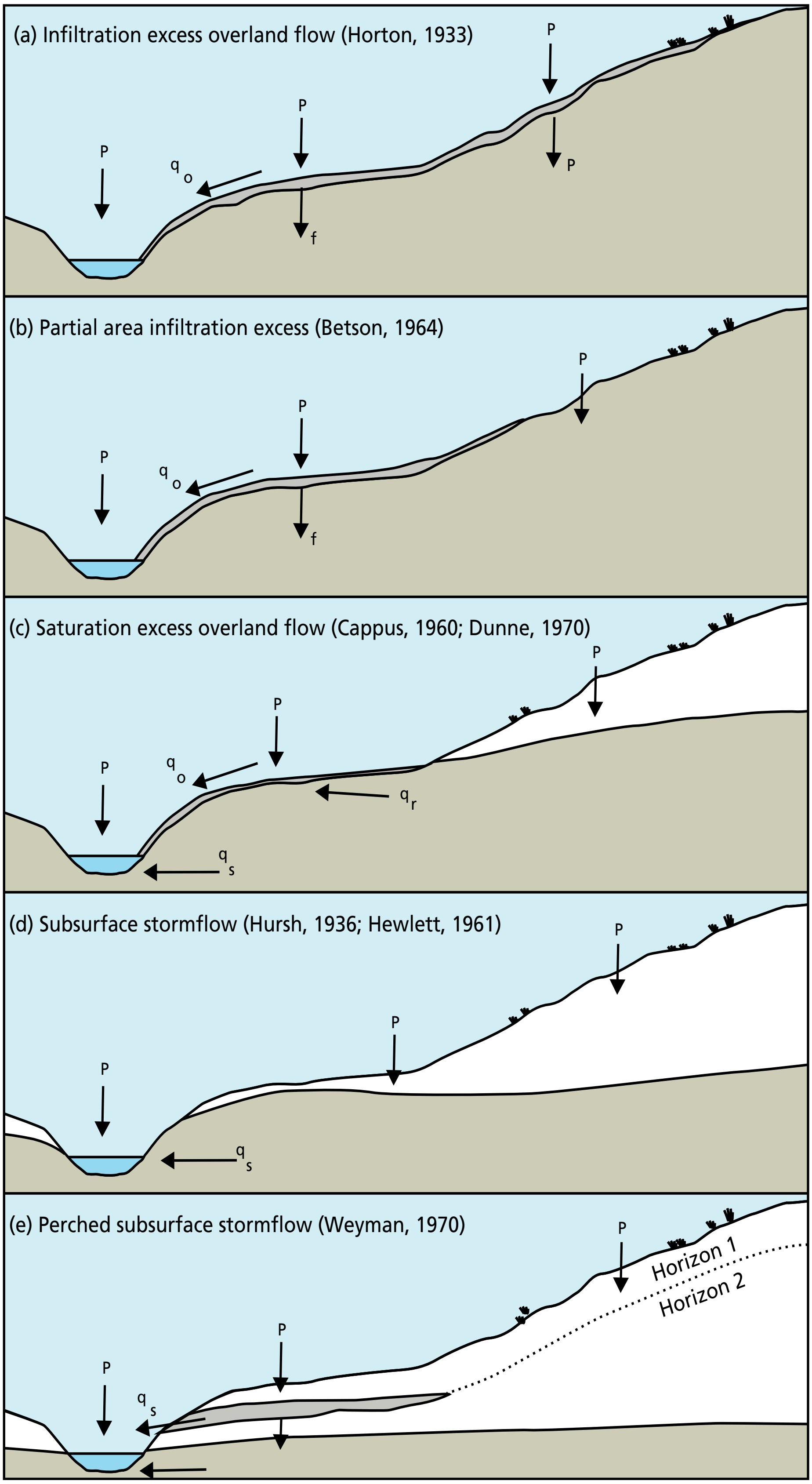
Source: Beven, 2012

Water balance analysis: Common problems

Although water balance analysis is relatively simple, it is easy to make mistakes. Published outputs of water balance analysis are often incorrect for reasons that include (After Burt, 1999):

- Temporal and spatial boundaries are not specified and/or delineated.
- Quality of input data is poor.
- Double counting of water flows, e.g. when return flows within a specified domain are added to flows exiting this domain.
- Inappropriate extrapolation of field level information to a larger-scale and vice versa.

FIGURE 3.15
Hill slope processes that generate overland flow (Qo)



Source: Beven,2012

- Storage terms are omitted from the water balance equation.
- Political, commercial and/or other pressures result in manipulation of the input data and/or the findings of water balance analysis.
- When estimating or modelling water balance components, insufficient account is taken of the:
  - Impact that unsustainable groundwater extraction and falling groundwater levels have on stream-flows.
  - Impact that watershed development; intensified rainfed farming; afforestation and other stream-flow-reducing activities can have on stream-flows and rates of groundwater recharge.
  - Impact that engineering structures and return flows can have on the stream-flow and groundwater recharge.
- Linked to the above, is a major concern that empirical relationships used in simple methods of estimating runoff and groundwater recharge can no longer be trusted in areas where the hydrology has altered markedly as a result of groundwater overdraft (particularly for irrigation) and expenditure on engineering, intensification of rainfed farming and other potential stream-flow reducing activities.

3.6.4 Water use fractional analysis

What are water use fractions?

In general, when water is diverted and used (e.g. for agriculture, industry or domestic purposes), a fraction of the water used is no longer available for reuse either locally or, say, downstream (e.g. because it has evaporated into the atmosphere). This fraction of water use is often referred to as the consumed faction (see Box 3.11). This consumed fraction can be further subdivided into water use or water use pathways that are beneficial or non-beneficial. (Karimi *et al*., 2013b)

The fraction of water that is not consumed when used or flowing along a water use pathway is referred to as the non-consumed fraction or return flows. By definition, this fraction returns locally or downstream. This non-consumed fraction can further be subdivided into fractions that are recoverable or non-recoverable (e.g. water percolating to groundwater is likely to be recoverable if the aquifer is not highly saline and non-recoverable, for most uses, if the aquifer is highly saline). It is the nature of fractions that further subdivisions are possible (see decision tree presented in Figure 3.16). Figure 3.16 highlights the fact that the water use pathways of recoverable and non-recoverable fractions can also be

BOX 3.11

Water use fractions

1) **Consumed fraction** comprising of:

(a) **Beneficial consumption** e.g. evapotranspiration from an irrigated or rainfed crop (but not the soil).
(b) **Non-beneficial consumption** e.g. evaporation from bare soil, weeds, roads and reservoirs.

(2) Non-consumed fraction comprising of:

(a) **Recoverable fraction:** e.g. deep percolation of excessive irrigation or rainfall to an aquifer without adversely affecting the water quality of this aquifer or treated urban wastewater.
(b) **Non-recoverable fraction:** e.g. water flowing into a saline sink or heavily polluted aquifer.

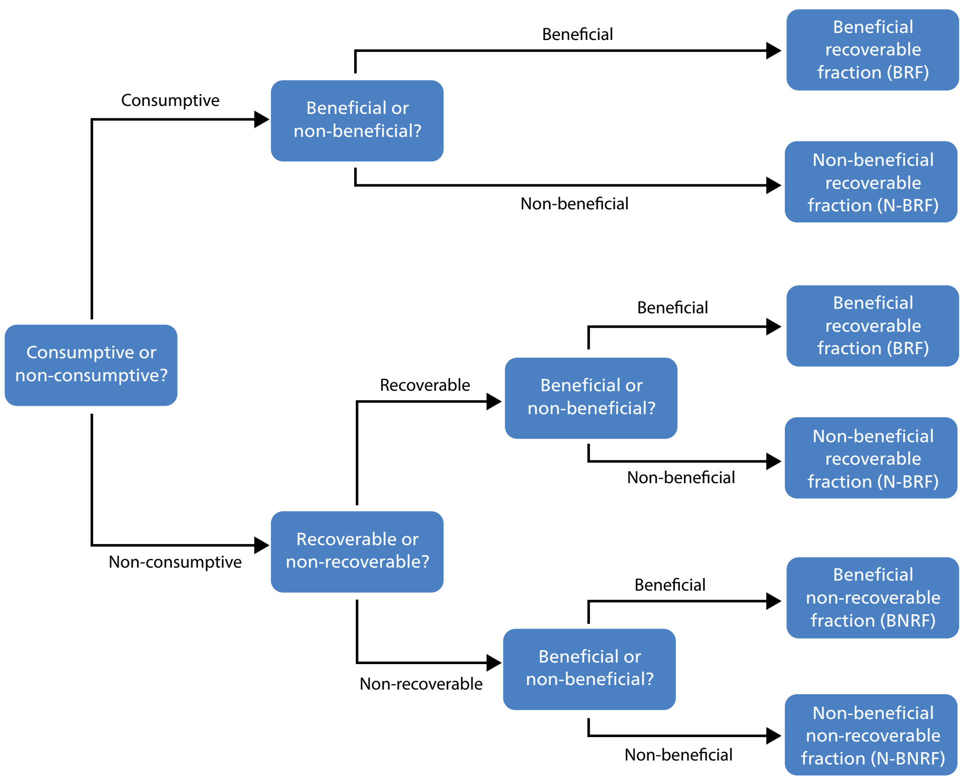
Source: Perry et al, 2009 and FAO , 2012.

beneficial or non-beneficial depending on the context. However, the more subdivisions there are, the more difficult or time consuming it is to use fractional analysis. Hence the recommendation is, as a general rule, to only use the four water fractions defined in Box 3.11.

What are the objectives of using water use fractions?

Interest in water use fractions has been driven primarily by confusion, misuse and misinterpretation of water efficiency terminology[44]. More specifically, there has been much controversy and debate about the engineering concept of 'water use efficiency' – the ratio between the amount of water evapotranspired by plants for productive purposes and the amount of water withdrawn or diverted from its source (Keller and Keller, 1995; Keller *et al*., 1996; Perry *et al*., 2009; Frederiksen and Allen, 2011; Gleick *et al*., 2011). It is now widely accepted that, while irrigation losses appear high, with on average about 40 percent of the water supplied to agriculture reaching plant roots, a large part of these 'losses' returns, locally or downstream, in the form of return flow or aquifer recharge. As important, this return flow may be re-used and/or serve important environmental functions (FAO, 2012). Measures to reduce losses upstream, while maintaining existing levels of withdrawal, will increase the productive efficiency of water use, but, at the same time, may deprive downstream water users who depend on water in rivers or groundwater aquifers that are fed in part by return flows (FAO, 2012). One of the objectives and merits of using fractional analysis is that it draws attention to the importance of return flows and the fundamental differences between water use pathways that are consumptive and non-consumptive (in space and time)

FIGURE 3.16
Partitioning total water use into fractions



Source: Penny, 2007; Pereira et al, 2012

44 Much has been published on water fractions, e.g. Willardson *et al.* (1994); Perry (2007); Perry *et al.* (2009); Foster and Perry, 2010; Frederiksen and Allen (2011); Perry, 2011; Pereira *et al.* (2012). Lankford, 2012; Lankford 2013; and Scott *et al*., 2014.

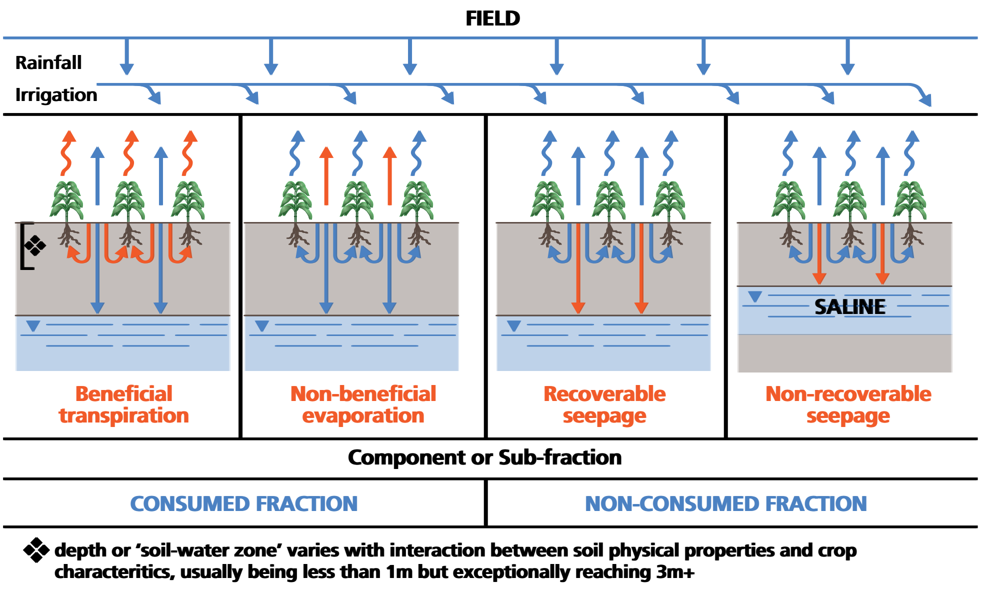
(See Figure 3.17). Fractional analysis also draws attention to the inter-connectedness of hydrological systems and, particularly, the fact that increasing consumptive water use in one part of a catchment or basin (either intentionally or without realising it) can impact on water users and uses elsewhere in the basin (as a result of the Law of Conservation of Mass).

At one level, fractional analysis is relatively simple, especially when used to analyse the water use pathways that are off-stream, and involve one type of water use (see Box 3.12). However even in simple cases, quantifying the water use fractions at this scale can be problematic because the empirical data are often lacking for direct measurement or for calibrating and validating models at the scales of interest. It is important to note that the relative magnitude is influenced by many factors that are highly variable in space and time (see Table 3.3). Given the high levels of variability and uncertainty, the water use fractions should really be presented as probability distributions rather than single values.

Using fractional analysis is much more challenging in contexts that: 1) Are characterised by mosaics of multiple sources and multiple water uses; and 2) Include the main watercourses (rather than being off stream). In addition, if the specified domain is not located in the headwaters of a catchment of a river basin it is likely that a large part of the water flowing into the specified domain will be: 1) Return flows from upstream; and/or 2) Committed (or nominally uncommitted) flows from upstream (rather than withdrawal). By making various assumptions and by using modelling this can be handled in fractional analysis (See Figure 3.18). However the analysis is complicated and interpretation of outputs is rarely as simple or as easy as the case study in Box 3.12. The risk therefore is that the process will remain prone to public misunderstanding, political capture and imprecise scientific thinking (After Lankford, 2012). If this risk is high a better option may be to use: 1) Hydrological and hydraulic modelling to produce information on the water balance components at different scales; and 2)

FIGURE 3.17

Typical vertical water use pathways for an irrigated crop growing on a permeable soil and unsaturated zone

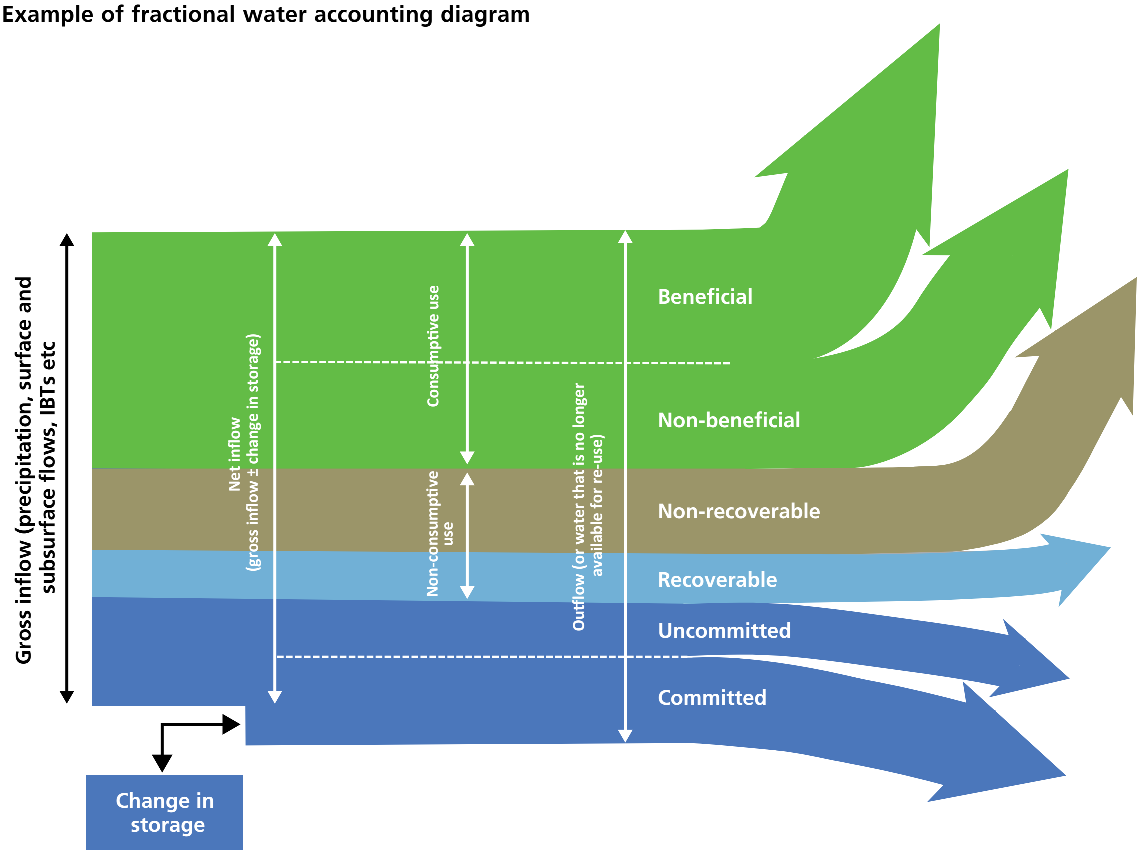


Source: Foster and Perry 2010

TABLE 3.3
Factors that can influence the relative magnitude of water use fractions

Space	Time
Spatial scales (e.g. field, farm, irrigation scheme, district, basin, etc.)	Different temporal scales (e.g. a single irrigation or rainfall event, a crop season, a year, a time series of many decades, etc.
Classes of land user or uses (e.g. irrigated or rainfed agriculture, forestry, urban, rangeland)	Length of the growing season
Irrigation type and water management/scheduling/ water allocation systems	Extreme events (e.g. prolonged droughts, floods, etc.)
Cropping system, land husbandry, pest management, etc.	Number of crops grown per year (i.e. intensity of land use)
Soil type, topography, rainfall, etc.	Changes in land use and management over time
Levels of water scarcity	Time lags between water capture and use (e.g. in terms of water stored in reservoirs, aquifers or the soil root zone)
Geographical location (e.g. proximity to sources, the sea, etc.)	Rainfall regimes (e.g. frequency, duration, intensity, number of rain days, etc.)
Condition of supply systems and other infrastructure	
Location, size and management rules of storages and bulk-water supply or transfer schemes	
Difference in retained subsurface or surface wate	

FIGURE 3.18
Example of fractional water accounting diagram

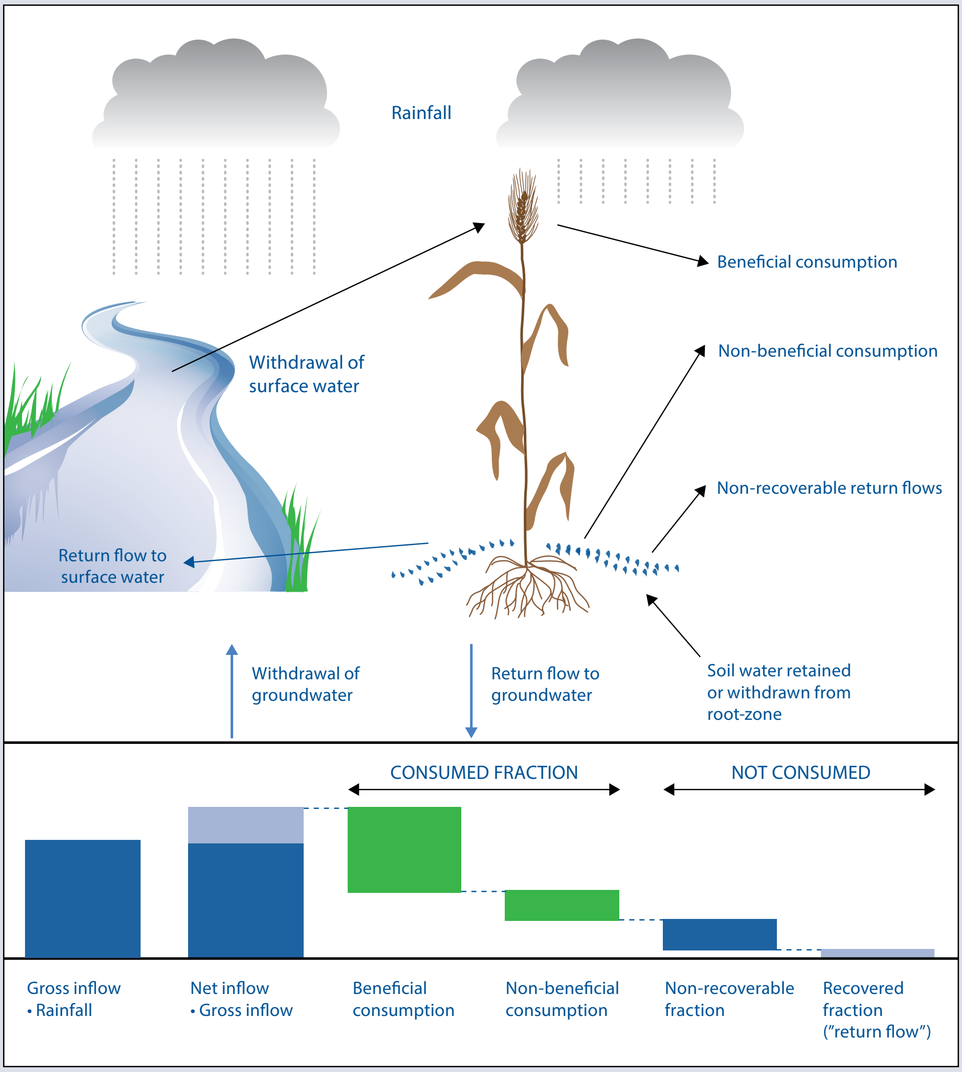


Source: Molden et a.l., 2003

BOX 3.12

Illustrative overview of water use fractions of an off-stream irrigation scheme

The schematic below presents a conceptual overview of water fractions associated with a field scale irrigation scheme that is withdrawing water from surface and groundwater. Water withdrawn from the sources can be divided into consumed and non-consumed fractions, the consumed fraction being the part of water withdrawn which evaporates, either directly from the soil or through plant transpiration. The non-consumed fraction leaves the field, either through deep percolation or flow to downstream land and watercourses. Part of the consumed fraction is put to beneficial use through crop transpiration or retained as crop water content, while non-beneficial consumption is lost through bare soil evaporation. Of the non-consumed fraction, a non-recoverable part will be lost to further use, either flowing to inaccessible groundwater sources, salt sinks or to the sea, or its quality will be affected to the extent that it cannot be used further, while the rest will flow downstream as return or recoverable flow and is available for further use.



Source: FAO, 2012

Fractional analysis for case studies that, for example, quantify return flows for some of the main types of water user and use.

Figure 3.18 is an example of an IWMI-style water accounting diagram that is based on the water use fractions recommended in this document. Committed (and currently uncommitted flow) is presented separately from recoverable flow on the basis that, committed river flows are, in many cases, not available for use in the given domains. It is just water that flows through these specified domains. Or, put another way, users within the specified domains may not have the right to divert these flows for consumptive uses. However, they may have the rights to use these flows for activities such a fishing or navigation (i.e. non-consumptive water uses).

BOX 3.13

Fractional analysis in Water Accounting Plus (WA+)

WA+ is a water accounting system developed by UNESCO-IHE in cooperation with FAO and IWMI that uses fractional analysis to report on the availability and use of water at basin level. It is essentially based on open-access satellite measurements, allowing computing of water consumption, flows, fluxes and storages by land use class. The approach makes a distinction between beneficial and non-beneficial, and consumptive and non-consumptive uses of water. The system is available through a dedicated platform at www.wateraccounting.org

Source: Karimi et al., 2013b

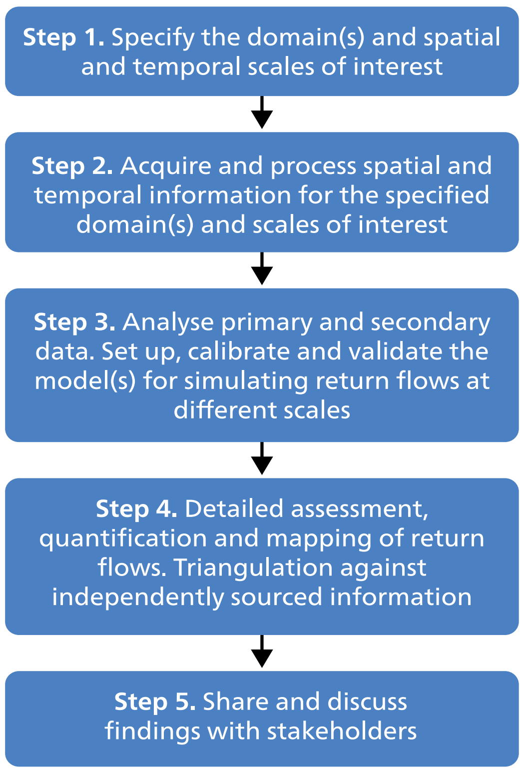
Water use fractional analysis: stepwise process

Important attributes of fractional analysis (see Box 3.13) and, more generally, the fractional approach to water accounting include: 1) It can be adopted for analysis of the water use of rainfed and irrigated farming systems; and 2) It can be adopted for analysis of any water-using sector – not just agriculture (Perry *et al.*, 2009). However, to be effective, fractional analysis must be based upon sound physical data, rigid consistent analysis of the water volumes involved and their disposition in time and space (Frederiksen and Allen, 2011). It is also highly desirable that stakeholders should have a good understanding of the methodology and outputs that are generated (Frederiksen and Allen, 2011). A typical process for using fractional analysis includes the following steps (See Figure 3.19):

Step 1: Specify the domains (space and time). Fractional analysis complements and builds on multi-scalar water balance analysis. Hence, the domains specified and the scales of interest are likely to be the same or similar. However, as mentioned above, fractional analysis is easier and possibly more useful when the focus is on a single water user or group of water users practicing a common activity (e.g. using the same irrigated cropping system). In such cases, it is easier to acquire and analyse necessary data and to communicate the findings to non-specialists. However, specifying and delineating larger more complex domains

FIGURE 3.19

Example of fractional water accounting diagram



BOX 3.14
Return flows and river basin planning

Estimating return flows is an important part of a basin-level water requirement assessment, because this is reusable downstream. Return flows can represent a significant portion of the allocable water in downstream parts of highly developed basins.

Source: Speed et al., 2013

is also possible and often needed given that return flows (see Box 3.14) are scale dependent. Similar to water balance analysis, it is important that domains for fractional analysis are delineated precisely.

Step 2: Acquire and process primary and secondary information. In most cases, much of the primary and secondary information needed for fractional analysis will have been collected, analysed and modelled as part of water balance analysis. In addition, empirical and/or observational information regarding return flows is needed in part because it is rare for return flows from irrigation schemes or urban areas to be part of monitoring networks. Strategies for acquiring information should also recognize that return flows are often highly variable in time and space as a consequence of: rainfall variability, operational mismatches between supply and demand, infrastructural breakdowns and geographical location.

Step 3: Analyse primary/secondary data and setup, calibrate and validate models for simulating return flows. This step centres on assessing and interpreting the primary and secondary information that has been collected (including the outputs from water-balance analysis and modelling). The availability (or lack of availability) of information may prompt a change in the modelling approach that is used. Once the models have been selected they should be calibrated and validated at the scales of interest. Section 5 describes typical procedures that can be followed.

Step 4: Detailed assessment, quantification and mapping of return flows. In most cases, this step will use modelling that focuses on the following:

- **Return flows:** The extent to which the recoverable fraction is re-used (or recycled) within or outside the specified domains. As important, who benefits from the return flow and the extent to which this reuse itself is consumptive or non-consumptive (see Box 3.14).
- **Variability:** The spatial and temporal variability of return flows and the underlying causes of this variability.
- **Time lags:** The extent to which water is stored (as a non-consumptive recoverable fraction) in reservoirs, aquifers and the soil profile over a period of time before being extracted or diverted to a consumptive or another non-consumptive use.
- **Sustainability:** Consideration of whether or not current levels consumptive water use are sustainable and/or the extent to which committed flows are being respected.
- **Productivity:** Fractional water use data can be used to estimate water productivity in time and space and produce maps of water productivity that can be used to analyse the absolute and relative values of productivity of water uses in space and time.
- **Efficiency:** Fractional water use data can also be used to estimate irrigation efficiency.

- **Externalities:** When considering opportunities that exist for increasing the beneficial consumptive use fraction or reducing the unrecoverable non-consumptive fraction, careful consideration should be given to potential externalities or perverse effects that might result within or outside the specified domain.

Step 5: Share and discuss findings with stakeholders. There is a deep-seated belief that improvements in efficiency are the route to freeing up large quantities of water for other uses. Consequently the findings from multi-scalar fractional analysis tend not to be readily accepted by many water professionals l*et al*one politicians, the media and the wider public. Hence, there is a high probability that some (or possibly most) stakeholders may reject findings from fractional analysis.

BOX 3.15
Access to data

Access to good quality data, particularly at the scales needed, is often a major constraint or limitation on fractional analysis and rigorous tracking and computation of water efficiency and productivity (Lankford, 2012; Van Halsema and Vincent; Pereira *et al*; 2012). However, the trend of increasing availability and accessibility of remotely sensed information is encouraging. Similarly, increased availability and use of GPS-enabled smart phones and open-source GIS software is opening up opportunities for improved data capture by 'citizen scientists'.

3.6.5 Water efficiency and productivity

Terminology

In most contexts, there is scope for managing the demand for water from agriculture and other sectors (in space and time). But excessive emphasis is often placed on the agricultural sector, with efforts that aim to reduce water 'losses' from water supply or distribution systems (see Box 3.17 and FAO, 2012). In many contexts, the scope for and impact of water loss reduction is limited because only part of the water 'lost' is non-recoverable either within or outside the specified domains. Fractional analysis should be used to: 1) Estimate the volume of non-consumptive water use that is non-recoverable in space and time; and 2) Provide the input data for calculating efficiencies of water use at different temporal and spatial scales.

BOX 3.16
Service performance indicators

A recent trend has been for Monitoring and Evaluation programmes to focus on service performance indicators rather than water efficiency and productivity indicators (e.g. Willardson *et al*., 1994; Bos *et al*., 2005; Merriam *et al*., 2007, Pereira *et al*., 2012; Moriarty *et al*., 2013). In recognition of the fact that benefits from irrigation (e.g. agricultural yields, farmers' incomes, etc.) often result from the level of services delivery experienced by users (Clemmens, 2006; Calejo *et al*., 2008; Zaccaria *et al*., 2010). Typical service level indicators include: volume (quantity and quality), reliability, dependability, adequacy, and equity (Pereira *et al.*, 2012).

BOX 3.17

Different perceptions of water efficiency

*F*or many (possibly most) farmers, concepts of water efficiency are linked to maximising the farms' economic productivity rather than saving water, except perhaps when their own allocated resources may be inadequate. As a consequence, using financial criteria for water efficiency, rather than an engineering criteria, appears to be a sensible approach when assessing irrigation performance at the farm level, since any managerial (e.g. scheduling) and operational (e.g. equipment) inefficiencies associated with irrigation are implicitly included in the assessment. Hence, the concept of catchment or basin level irrigation efficiency is largely irrelevant to most farmers. Instead they aim for the best use of a potentially limited water supply, aiming not to over or under irrigate, whilst minimising any non-beneficial losses. This is often described as 'applying the right amount of water at the right time in the right place'. Any water 'saved' would be allocated to additional crops. In contrast, water regulatory authorities or similar, whose prime objective is to balance the water needs of all abstractors (including the aquatic environment) generally view increasing water efficiency as a means of saving water and promoting environmental sustainability.

Source: Knox et al., 2012

In most cases, the single most important avenue for managing water demand in agriculture is through increasing agricultural productivity with respect to water. An increase in crop yield (production per unit of land) is the most important source of crop water productivity increase. Yield increases are made possible through a combination of improvements in water management in rainfed and irrigated cropping systems, land management and agronomic practices. This includes the choice of genetic material, and improved soil fertility management and plant protection. It is important to note that plant breeding and biotechnology can help by increasing the harvestable parts of the biomass, reducing biomass losses through increased resistance to pests and diseases, reducing soil evaporation through vigorous early growth for fast ground cover, and reduced susceptibility to drought. Therefore managing overall demand through a focus on water productivity rather than concentrating on the technical efficiency of water use alone is an important consideration (FAO, 2012).

If productivity is considered in terms of added value and not production, reallocating supply from lower value to higher value crops is an obvious choice for farmers seeking to improve income levels. For this to happen, changes are required in both the management and technology associated with irrigation to provide farmers with a much higher level of control of water supply. In addition, shifts to higher value crops also require access to inputs, including seeds, fertilizers and credit, as well as technology and know-how, and reasonable conditions to operate under more competitive market conditions. However, in practice, very few farmers are able to make this choice since the market for higher value crops is limited compared with the market for staples. Beyond productivity concerns, agricultural water demand can simply be limited or capped. This is a commonly applied measure where the volume of evapotranspiration used in the production of a unit of agricultural output is limited by reducing the area under irrigation (FAO, 2012).

Irrigation efficiency

Generically, 'water efficiency' is a dimensionless ratio that can be calculated at any scale and used for different classes of water supply and use (e.g. an inter-basin transfer system, a town water supply network). In the agicultural sector, it is referred to as irrigation efficiency (IE) and is used to assess and monitor system losses that can be classified as non-beneficial water use fractions that may be non-recoverable (e.g. evaporation from a canal) or recoverable (e.g. seepage from unlined canals). The attractiveness of irrigation efficiency as an indicator is embedded in its constituent parts that distinguish conveyance efficiencies from application efficiencies. The net result for a specified domain is that IE neatly distinguishes the irrigation engineering/ management efficiency from the farmer/agronomic efficiency (van Halsema and Vincent, 2012). However, it should be noted that IE estimates are less comparable than sometimes implied because they are scale dependent, both in time and space – this hampers comparison of IE values, across scales, time-frames and localities (Van Halsema and Vincent, 2012). In this sourcebook, irrigation efficiency for a specified domain is defined as a ratio:

$$IE = Q_{Req} / Q_{Div}$$

Where Q_{Req} is the volume of water required for irrigation (which includes water needed for crop transpiration, leaching to prevent salinization, weed control, etc.) and Q_{Div} is the volume of water diverted from the source of supply.

Also recommended is limitation of the use of IEs to their constituent components of conveyance efficiencies (e.g. primary, secondary, tertiary canals or an irrigated area under the command of a borehole) and application efficiency (plot, farm), where they can attribute clear value to the specific technological function of irrigation components – no more, and no less (van Halsema and Vincent, 2012).

Water productivity

Increasingly water productivity (WP) is being flagged as an important issue in relation to global and regional food security (Molden *et al*., 2003, 2010; Clemmens and Molden, 2007). A consequence is that attention formerly given to irrigation efficiency is being transferred to water productivity (Pereira *et al*., 2012). Increasing the WP of irrigated and rainfed agriculture is thereby seen as the critical element in increasing agricultural production without major increases in fresh water diversion to agriculture particularly in regions facing increasing water scarcity (van Halsema and Vincent, 2012; FAO, 2012).

It is recommend that water productivity for a specified domain be defined and derived as:

$$WP = Y_{Actual} / QB_{cf}$$

Where QB_{CF} is the volume of water that is beneficially consumed in a specified domain or another unit of analysis and YA_{CTUAL} is the actual crop yield.

The WP concept can also be applied in a wider sense, by attributing different values to the [product] in the numerator. This is common in water valuation approaches, where economic attributes can be given in monetary terms ($m–3); social attributes (jobs, food security, etc.), or environmental attributes (carbon sequestration, biodiversity, etc.) (Turner *et al*., 2004; Knox *et al*., 2000; Renault and Wallander, 2000). The attractiveness of economic valuation is that it provides a method to compare economic WP values not only across scales, but also across production systems such as crops, energy, fisheries, livestock (van Halsema and Vincent, 2012). However there are some potential pitfalls or challenges associated with economic water productivity analysis (see Box 3.18).

It should be noted that considerable confusion and questionable interpretations occur when the definition and value of the denominator in the equation above is substituted with total water use (or total water applied). This latter mishandling of the WP concept tends to hide rather than explain the potential trade-offs and reallocations of water uses and users in a water scarce basin when increases in agricultural production are propagated; see examples provided by Perry (2007). To avoid confusion, the WP concept should be defined with the denominator as water beneficially consumed rather than total water use (van Halsema and Vincent, 2012).

A big advantage of the WP parameter is that any absolute increase in water consumption monitored equates unequivocally with an absolute increase in water depletion within the hydrological domain. [45] This forces explicit consideration of any increase or decrease in water consumption in terms of a re-allocation of actual water use within the hydrological domain (van Halsema and Vincent, 2012).

Water use efficiency

Although the term 'water use efficiency' is widely promoted and used, a universal definition has yet to be agreed and adopted (Steduto, 1996; Pereira *et al*., 2002; Hsiao *et al*., 2007; Perry, 2007, Van Halsema *et al*., 2012; Pereira *et al*.; 2012). In the water sector, the term 'water use efficiency' is generally understood to be a dimensionless ratio between water use and water withdrawn, while in the agriculture sector it is often used to measure the efficiency of crops (irrigated or rainfed) to produce biomass and/or harvestable yield (Pereira *et al*., 2012). The net result has been many miscommunications and misunderstandings at the policy level in both the agriculture and water sectors. Therefore, it is recommended that the term 'water use efficiency' be avoided, and use should be made only of either 'irrigation efficiency' or 'water productivity' calculated according to the equations above.

Finally it is recommended that, in most cases, 'water productivity' should be the metric of choice given that it is not scale dependent, unlike 'irrigation efficiency', and the 'water productivity' concept can be applied in a wider sense by, for example, redefining the numerator in monetary terms.

3.7 TIPS AND TRICKS

Practical lessons that have been learned from using water accounting include:

- Quality controlling of secondary information using filtering, triangulation and other techniques, is a crucial step in water accounting that often requires a lot of time and patience.
- Water accounting is relatively easy for people with enquiring minds who also have an interest in multi-disciplinary analysis. It is not so easy for people who prefer to work within the limits of their respective areas of specialisation.

[45] When increased production (and water productivity) in rainfed agriculture is achieved, as currently widely attempted, the resulting diminished replenishment of aquifers and rivers can be assessed by quantifying the resulting increase in actual evapotranspiration of these improved agricultural practices

BOX 3.18

Potential pitfalls of economic WP analysis

- Economic WP values do not necessarily equate to crop yield WP values, i.e. maximum net income of a farmer may be achieved at lower levels than maximum yield productivity.
- Economic WP values are susceptible to the vagaries of the markets and economy.
- Methodological complications arise for extension of WP to non-consumptive production processes such as hydropower, fisheries, recreation and biodiversity (to some extent).
- Additional benefits of irrigation for other agronomic activities (e.g. aiding harvesting, frost protection, disease control, etc.), which are not directly part of increasing yield and crop value tend to remain un-assessed.
- Additional water valuation methods need to be deployed to capture broader societal benefits of water use (e.g. jobs, food security, poverty reduction, etc.).

Source: Van Halsema and Vincent et al., 2012

- Specialists play a vital role in accounting procedures.
- The knowledge of local-level stakeholders should not be under or over-estimated. Village-level stakeholders can provide real insights into the nature and severity of change processes in and around their villages. Local-level stakeholders, however, tend to be less reliable when it comes to identifying the causes of these changes.
- Water balance estimates are often presented as being precise. In fact, there is always uncertainty that arises from, for example, inadequate hydrometric information, inaccurate measurements or estimations; and the complex spatial and temporal heterogeneity that characterises hydrological processes.

4. WATER AUDITING

4.1 AIMS OF THIS SECTION

This section describes the FAO approach to water auditing that, in most cases, will be carried out in parallel with water accounting. The rationale behind water auditing is that problems of equitable, sustainable and efficient access to water and/or water services are often rooted in politics, economics, power asymmetries and a range ofsocio-cultural factors (Molden *et al*., 2007). As a consequence, water accounting alone is rarely sufficient to identify, describe and quantify all the underlying causes of, for example, unsustainable use of water resources or inequitable water services delivery. More positively, water auditing can also be used to identify and assess opportunities for improving environmental sustainability and water services delivery.

The key aims of this section include: 1) Highlighting benefits, synergies and added value of using water auditing alongside water accounting; 2) Describing how best to assess and analyse the governance, institutions, public and private expenditure, legislation, water services delivery and the wider political economy of the specified domains; 3) Listing some of the typical objectives and challenges linked to designing and using water auditing; 4) Describing practical approaches that can be used, for example, when structuring governance assessments and/or political economy analysis; and 5) Describing a generic stepwise process that can be followed when using or applying water auditing in specified domains.

4.2 WATER AUDITING STEPWISE PROCESS

Typically, the first four phases of a water auditing process are part of an iterative cycle that starts with detailed water planning or updating of plans (see Figure 4.1). The general recommendation is to actively engage stakeholders in all of these phases and to ensure that water accounting and auditing are mutually supportive. The latter can be achieved through cross-cutting activities such as ensuring that plans for primary and secondary data collection are well aligned (see Box 4.1).

Typically, the main focus of water auditing in these first four phases is on investigating the societal causes of water-related issues and concerns that have been highlighted and prioritised by key stakeholders. If this goes well, insights will be gained into the broader context of governance, institutions, public and private expenditure, legislation and the wider political economy of the specified domains. These insights will help characterise the specified domains from a societal perspective and to identify societal issues and concerns that may require further more detailed investigation.

Effective information acquisition and management as well as integrated analysis and modelling are at the heart of both water accounting and auditing. So, to avoid fragmentation and repetition, guidance on these activities is consolidated in Section 5.

4.3 DETAILED WATER AUDITING PLANNING

4.3.1 Revisit and update water auditing plans

At the beginning of each iterative cycle of water accounting and auditing it is usually necessary to revisit and update plans produced during the inception phase. Reasons for this include:

- New stakeholders (or new representatives of existing stakeholders) may have become involved and/or joined the multi-stakeholder platform.

- An implementation team may have been mobilised.
- Available funds and institutional arrangements for implementing the programme may be different to how it was originally envisaged during the inception phase.
- Organizing stakeholder meetings at the beginning of a project can raise awareness that the programme has started. Especially, if meetings are announced and reported by the media and on social networks.

BOX 4.1

Who should participate in water auditing?

If the group of interested stakeholders who would like to join a multi-stakeholder platform is too large, it can complicate matters and increase costs. In some cases, just getting everyone to the same meeting can present significant logistical challenges. However, if non-government stakeholders are left out of, for example, a governance assessment, the credibility and legitimacy of this assessment will suffer. This said, it is imperative that government stakeholders also be included, because the process of assessing governance is a political exercise. In conclusion, including both government and non-government stakeholders increases the political legitimacy of the process internally and externally

Source: UNDP, 2009

BOX 4.2

Alignment of water accounting and auditing

When designing and implementing water accounting and auditing, it is highly desirable that that the two processes:

- Share the same institutional arrangements and, if relevant, the same multi-stakeholder platforms;
- Follow a similar stepwise process;
- Specify temporal and spatial domains, institutional levels and scales of interest that are the same or reasonably well aligned;
- Share office space, transport and other logistical arrangements;
- Be under the leadership of the same team leader or government officer;
- Use modelling, scenario analysis and similar methods for combined water accounting and auditing analysis;
- Share the services of a professional information manager;
- Share information and findings;
- Use the same or compatible terminology and frameworks e.g. for organising and managing information;
- Organize joint meetings, workshops, etc.;
- Develop and use a combined communication strategy.

FIGURE 4.1
The first four phases of a typical water auditing process

1. Detailed water auditing planning

- For the first iterative cycle, finalise planning activities started in the inception phase. For subsequent iterative cycles take account of lessons from previous cycle(s of water accounting & auditing e.g. modify/adapt domains, strategies, methodologies etc;
- Stakeholder dialogue and concerted action leading to prioritisation of next cycle of activities, assessments and analysis;
- Agreement on expected outputs of next cycle of activities.

↓

2. Societal information acquisition & management

- Combined societal and biophysical Information needs assessment;
- Identification of secondary information sources for current cycle. If relevant, planning & implementing a programme of primary information collection;
- Information acquisition, processing and quality control
- Storage and sharing (e.g. data, metadata, reports, maps, photographs etc.

↓

3. Targeted societal assessments

- Plan and implement targeted assessments of, for example: governance of; institutional roles & responsibilities; public & private finance and expenditure; formal & informal laws; and, the wider political economy;
- Compare/triangulate findings/outputs against information from independent sources;
- Share and discuss outputs/findings of each assessment with key stakeholders. Resolve differences of opinion and take account of feedback.

↓

4. Multi-level analysis of e.g. drivers of change, power asymmetries, incentives and behaviour

- Combine outputs and findings from targeted assessments and subject these to more detailed analysis with the aim of better understanding historic and current drivers of and/or constraints on change;
- If possible also, detailed multi-level analysis also of e.g.: power asymmetries; stakeholder behaviour, values and incentive systems; and the reasons for sanctioned discourses and water-related myths and misunderstanding;
- Consolidate, share and discuss findings and outputs with stakeholders

At the beginning of subsequent iterative cycles of water accounting and auditing it is advisable to review the work to date and to revise or adapt the plans for the next cycle. The key point is that plans should be revised to take account of the lessons learned or issues raised by water accounting and parallel water auditing activities. In terms of water auditing, it is important to recognize that politically sensitive issues can arise and that some (or even all) stakeholders may not want to address or discuss. In such cases, sensitive and tactful facilitation is needed that may involve 'setting aside' issues with a view to, if possible, returning to them in a subsequent iterative cycles (see Box 4.3).

4.3.2 Identify and (re-)prioritise societal issues and concerns

If at all possible, identification and (re-)prioritisation of issues and concerns should be an activity that cuts across water accounting and auditing. It also provides a good opportunity for multi-stakeholder platforms to exert some level of control over the focus of both water accounting and auditing during each iterative cycle. However, facilitation of stakeholder discussions will be needed to: 1) Ensure that a few powerful stakeholders do not dominate discussions and 2) Adequate consideration is given to a wide-range of issues and concerns in recognition that some of these may be predominantly biophysical and while others may be predominantly societal.

Additional guidance on identifying and prioritising issues and concerns can be found in Section 3.3.2.

BOX 4.3

What to do with sensitive information

Water auditing often generates findings, outputs or recommendations that are politically, culturally or professionally sensitive. These can and should be shared and discussed routinely with key stakeholders albeit in a low-key manner. A process of openness is likely to have a more positive effect than: 1) Only sharing and discussing findings after the water auditing has been completed; or 2) Discarding anything that could be sensitive. By having ‘recent findings’ as a regular agenda item for learning alliance meetings, water auditing can also play an important role in gradually and tactfully raising the bar on what can or cannot be debated.

Source: EU, 2008

4.3.3.Develop and update perceptual models

Developing and updating perceptual models helps stakeholders to move beyond listing ‘problems’ (often in the form of reformulated solutions such has lack of funds, staff and other resources) to identifying the causes of problems, issues and concerns and most important effects. It is important to note also that stakeholders tend to view and frame problems from their own perspectives. The net result is one stakeholder’s problem may be viewed by another stakeholder as something that, rather than being a problem, is beneficial to them (e.g. return flows are often viewed as a water loss by upstream irrigator farmers whereas downstream irrigator farmers will view the same return flows as an important source of water).

Additional guidance on developing and updating perceptual models can be found in Section 3.3.3. A key point is that the development or updating of perceptual models should not be an academic exercise. Instead it is an attempt to consolidate perceptions or understanding in a graphical format that can be shared and discussed. As mentioned in Section 3.3.3, this could be a simple problem tree or cause and effect diagram. Given the aims of water auditing, it could also be a simple theory of change diagram[46].

4.3.4 Re-specify and delineate societal domains of interest

From the perspective of water accounting, boundary issues are a fact of life that have to be acknowledged and accepted (FAO, 2012). Political, administrative, management and hydrological boundaries and units rarely coincide. This is not so important when, for example, hydrologists or managers of irrigation schemes are working within their own professional silos. It is important, however, when these professionals are working together on a water accounting and auditing programme. The general rules are to

- Be pragmatic when specifying and delineating boundaries and units. This usually leads to specifying and delineating biophysical and societal boundaries and units that are similar and reasonably well aligned but not the same.
- Take account of the availability of biophysical and societal secondary information at the scales that are selected.

[46] Drawing the theory of change diagram can be a good way of structuring stakeholder dialogue around change processes. However, the resulting diagrams are often too complicated to be of any value to anyone who was not directly involved (Green, 2013).

- Use the boundaries and units that are most relevant (e.g. use administrative boundaries when assessing the performance of government-supported programmes and use the boundaries of an irrigation scheme when assessing the issue of equitable access to irrigation water).
- Further address boundary issues when moving on to integrated and interdisciplinary analysis.
- Make good use of GIS and spatial analysis in all of the above.

It is also important to recognize that policies, legislation and fiscal measures at the national level often profoundly affect what happens at the district and local levels, most importantly in setting boundaries for stakeholder involvement in decision-making and, more specifically, in formalizing their roles and responsibilities (Moriarty *et al*., 2010). Decisions outside the typical boundaries of biophysical and societal domains, such as those concerning energy prices, trade agreements, agricultural subsidies and poverty reduction strategies, also often have a major impact on water supply and demand, and hence on levels of water scarcity experienced by different water users and uses within the domains selected (FAO, 2012).

4.3.5 Update the communication strategy

It is advisable to update strategies regularly used for communication within the water accounting and auditing implementation team, with key stakeholders, the media and more broadly with the general public. If multi-stakeholder platforms have been set up at different institutional levels, vertical communication between platforms should be considered.

More guidance on communication strategies can be found in Section 6.3.

4.3.6 Availability of funds and other resources

Funds: At the beginning of each iterative cycle of water auditing, it is advisable to check that the available funds match the water auditing commitments and levels of ambition.

Specialist skills and experience: Typically water auditing requires specialist skills in the following disciplines: institutional development, social development, political science, legislation, statistics, spatial analysis and information management. The mix of disciplines will, of course, vary with the issues and concerns in the specified domains. Also, in most cases, it is not necessary to seek the services of a large number of specialists. Rather the challenge is to seek out individuals who are able to provide a range of inputs and who also have the aptitude for interacting and engaging with stakeholders and non-specialists.

Hardware: GPS sets (or GPS-enabled smart phones), cameras, laptop or tablet computers. When GPS sets were relatively expensive, they were usually purchased for and used by the biophysical members of a water accounting and auditing team. Today it is common for all members of teams to use GPS sets in recognition that the geographical location often has a major influence on, for example, access to water and the water services of different social groups.

Software: GIS, database, spreadsheet, statistics, cloud-based data storage and teleconferencing. Note that open-source software is increasingly available that can be used during water accounting and auditing (this includes open-source GIS software).

Specialist software is also increasingly available to support the analysis of societal information (e.g. for network analysis, problem tree analysis, mind-mapping, etc.).

4.4 SOCIETAL INFORMATION ACQUISITION AND MANAGEMENT

4.4.1 Societal information needs and availability assessment for the current cycle

As mentioned in Section 3.4.1, information needs assessments are crosscutting activities that consider the information that is needed and available for each cycle of water accounting and auditing.

Typically societal information needs assessments are guided by considerations that include: 1) Issues, concerns and opportunities that have been identified and prioritised by stakeholders; 2) Findings from other studies or from earlier rounds of water accounting and auditing; 3) Well-informed opinions of specialists who have a good understanding of the societal context; 4) Information (and metadata) requirements of the methods of analysis and modelling that you expect to use; 5) Perceptual models that have been developed and updated after each cycle of water auditing; and 6) Evaluative questions that have been identified by specialists supporting the water auditing.

Some other points that are relevant to societal information needs assessments include:

- **Stakeholders** are an extremely rich source of societal information on the current status, trends or timelines of institutions, governance systems, legislation, finance and the wider political economy. This information can be elicited using for example key informant interviews, focus groups discussions, surveys and workshops. A general point to remember when obtaining information from stakeholders is that there maybe significant biases (Cowling *et al*., 2014). As a result, it is important, when engendering information or documenting events to identify and keep a record of potential biases.

Much of the information elicited from stakeholders is based on their judgements, opinions and perceptions and based on metrics that are important but difficult to quantify e.g. satisfaction, influence, power, awareness, attitude and understanding (UNDP, 2013). This type of subjective information is usually captured using surveys or interviews.

If resources permit, water accounting and auditing engages with stakeholder regularly using multi-stakeholder platforms. Active members of these platforms are usually very willing to be sources of information for water auditing and/or to help elicit information from other stakeholders who may not be so active. Typical benefits of eliciting information from different type of stakeholders can be summarized as follows (after Cowling *et al*., 2014):

- **Government:** Much knowledge about governance, institutions, legislation, finance and political economy issues resides in the brains of people working for the government at different institutional levels. Typically, many government departments have a stake in and knowledge or views about water-related issues and opportunities albeit from their own perspective.
- **Regulators, agencies and control boards:** Senior officers from a range of quasi-government organizations (e.g. independent regulatory authorities, pollution control boards, environment agencies, river basin organizations) often have interesting experiences and insights that they are willing to share.

- **Water user groups** and other consumer organizations represent the users of water services in rural, peri-urban and urban areas. Their perspectives on issues and concerns often differ significantly from those of organizations that are responsible for delivering water services to different water users.
- **Academia:** Staff from universities, institutes and training centres that have been involved in or have knowledge of earlier or ongoing water-auditing studies. If an academic or a trainer is respected and seen as being relatively neutral, he or she may make a good facilitator for workshops or focus group discussions.
- **NGOs**: Staff from grassroots NGOs often have more experience and knowledge of local-level realities than, for example, academics. Activist NGOs are a good source of information in terms of issues relating to poor and marginal groups or the status of environmental flows.
- **The Private sector** is a major user of water services and, in some cases, actively involved in the delivery of water services. Even in countries with little or no privatisation of water services delivery, there is a reliance on the private sector for the manufacture of pipes and pumps and the construction of storage structures and wastewater-treatment plants. Private sector stakeholders, in particular, have a lot of information on the capital and recurrent costs of water supply, storage and treatment systems. Similarly, the private sector is often involved in post-harvest technology and food processing. Hence they have particular insights into different type of losses (including water) along value chains[47].
- **Farmer organizations and unions:** Agriculture is a major consumer of water and agricultural landscapes also perform important environmental functions. Hence the views of farmers or their representatives on, for example, drivers of change with regard to agricultural intensification are important and are often very different to the perspectives of academics and policy-makers.
- **Development and donor agencies:** Staff in development agencies may prefer not to express opinions. However, they can often: 1) Be a useful sources of background information; 2) Play a role in the verification and validation of information; and 3) Direct survey teams towards people who may not be stakeholders, but who have knowledge that is particularly relevant to the specified domains.
- **Other stakeholders:** This list of stakeholders is far from exhaustive. Many other, or possibly different, stakeholders will be identified in typical water auditing processes.

Secondary information

Analysis of secondary information that is a central component of the information needs and availability assessment that takes place during a first round of water accounting and auditing. Information needs and availability assessments during subsequent rounds of water accounting may focus more on findings from the previous round of water accounting and issues, concerns and opportunities identified by stakeholders and specialists. Typical sources of societal secondary information are listed in Box 4.4.

[47] Food loss and waste occur all along the food chain, from harvesting to transportation, storage and packaging. Further losses occur in food processing, wholesale and retail trade, and in consumption by households. It has been estimated that losses and wastage may be in the order of 30 percent between the field and end user (FAO, 2012).

BOX 4.4

List of typical sources of societal secondary information

- Reports, official records, academic studies, NGO studies or documentation, etc.
- Official minutes of meetings of e.g. district councils, river basin authorities, etc. – may be available on request
- Organization charts or institutional organograms – often available on government web sites
- Census data – available online or from government statistical departments
- Published policies and laws – available online or from government publishers
- Grey literature – this is unpublished documentation that is often available on request
- Budget documents – available online or from finance departments
- Media reports – available online or from journalists
- Maps e.g. cadastral maps, maps associated with plans – available from planning departments
- Web sites – searching or trawling the web often produces information that is both unexpected and useful
- Social media – blogs, tweets and new forms of social media

Evaluative questions

There are four types of evaluative question[48] that can be useful when deciding what societal information may be needed in each cycle of water auditing:

- **Descriptive questions:** What is happening? What is changing? Who is benefiting?
- **Causal questions:** What is causing or prompting changes?
- **Synthesis questions:** Are there externalities? Who is advocating change?
- **Action questions:** What should happen next? What are the drivers or opportunities for change?

Primary information collection

When compared to water accounting, water auditing often has to rely more on primary information that is qualitative while making good use of any secondary qualitative and quantitative information that is relevant to the specified domains.

4.4.2 Information acquisition, processing and quality control

As stated in Section 3.4.2, information acquisition, processing and quality control take time, skill and patience. The key steps are to: 1) Develop a strategy for acquiring and managing societal information bearing in mind the fact that information is likely to be both qualitative and quantitative; and 2) and ensure that the personnel responsible for this work have had the necessary training and are well motivated.

[48] After Buffardi *et al.* (2015)

BOX 4.5
Practical tips for interviewers

A good interviewer:

- Honors basic courtesy.
- Remembers participants' names and titles and uses appropriate forms of address.
- Uses body language and eye contact appropriately to engage with participants.
- Spends most of the interview listening rather than talking.
- Uses active listening, follow-up questions, and other techniques to assure that answers have been correctly understood and to encourage people to contribute complete information.
- Keeps the purpose of the interview in mind and uses good judgment to achieve that purpose (even if it means deviating a bit from the protocol).
- Remembers to thank participants.
- Does not raise undue expectations about what participants' input or the assessment will deliver.

When compared to water accounting, water auditing usually requires:

- More resources for primary information acquisition because it is rare for sufficient secondary information to be available for specified domain.
- More training for the teams responsible for collecting primary data because collectively they are expected to be skilled in:
  - Interviewing, facilitation and conflict resolution and documentation (see Box 4.5).
  - Acquiring robust information related to abstract concepts such as governance[49].
  - Documenting, among others, key informant interviews and/or focus group discussions.
  - Organizing multi-stakeholder processes, remaining neutral and, maintaining the respect of the people they are facilitating.

Some typical methods of societal information collection are described in Table 4.1. Additional practical guidance on planning and implementing societal data collection can be found in Cowling *et al.*, 2014[50].

4.4.3 Storage and sharing of data

Information and associated metadata need to be stored and shared in forms and formats that are easily accessible. It is advisable to use a structured information base that stores information on the cloud. Internet based commercially available systems for storing and sharing digitised information (e.g. Dropbox or Google drive) are easy to use and an alternative to, for example, creating a more complex management information systems. In all cases, however, disciplined structured management of information is needed to ensure that raw, processed and simulated information is not unwittingly mixed together. More information on information management can be found in Section 5.

[49] Food loss and waste occur all along the food chain, from harvesting to transportation, storage and packaging. Further losses occur in food processing, wholesale and retail trade, and in consumption by households. It has been estimated that losses and wastage may be in the order of 30 percent between the field and end user (FAO, 2012).

[50] The focus of this practical guide is on assessing forest governance. However, the principles followed and practical guidance provided are also applicable to water auditing.

TABLE 4.1
Typical methods of societal data acquisition

Methods	Descriptions
Desk reviews	Desk studies are usually undertaken by consultants or academics because they are familiar with the jargon used and they are often better placed to evaluate the value and quality of material that they review. These assessments may rely on archival data, administrative data, narrative reports, laws, legal documents and government statistics, as well as the opinions of key informants. Increasingly, desk studies are based on material that can be mined or trawled from the web. Desk studies, however, often suffer from a lack of local context and experience when conducted by external experts. The use of local academics or other experts may rectify this problem. Regardless of whether external or local experts are used, these studies tend to represent the views of experts who may be tempted to give more weight to their own opinions than, for example, the opinions of key stakeholders.
Accessing online databases	Increasingly, biophysical and societal data can be accessed and downloaded at no charge from online open-access databases e.g. http://info.worldbank.org/governance/wgi/index.aspx#reports. The information tends to be coarse but the ease of access often makes this information a good starting point for any data collection procedure. Note that good IT skills may be needed to download and reconcile data from online sources because the forms, format, units and scales used may differ.
Surveys	The term 'survey' encompasses a range of tools, including structured and semi-structured questionnaires. Increasingly online surveys are being used that are open access or that involve targeting of potential respondents. Advantages of surveys include the possibility of their being administered on a range of scales (i.e. large or small numbers of respondents across a large or small geographical area); responses can be analysed statistically and spatially; and, they can be relatively cheap. However, the number of survey respondents can be low and the level of thought given to responses is often minimal.
Expert analysis	Expert analysis centres on one or more experts providing analysis based on their own knowledge, research, or experience of the sector. These experts could be members of the water accounting and auditing team; the multi-stakeholder platforms; or some kind of advisory panel or steering committee. Clearly the opinions of these experts should be elicited and valued. However, the experts should be asked to provide independent evidence to back up their views or proposals.
Key informant interviews	Key informant interviews involve interviewing individuals who may be, for example, senior government officers; specialists working for an NGO; or citizens who have worked and/or lived in the specified domain for some time. Since interviewing these informants on a one-to-one basis uses time and other resources, it is important that they provide insights that cannot be gained by other methods, e.g. they can explain how and why changes have taken place in institutional structures or farming systems. Note that using a structured or semi-structured interview protocol can help to ensure that there is consistency and comparability across interviews.
Focus group discussion	In focus-group discussions, selected stakeholders meet to discuss specific issues. Usually discussions are semi-structured and facilitated. The stakeholders can be experts or a sample drawn from specific social groups of interest. Focus group discussions often provide a good opportunity for validating provisional findings. Unlike a key informant interview, it is likely that views or positions held by an individual will be challenged as part of the focus group discussions.
Target group discussions	Target group discussions are designed to learn more about the experiences and opinions of vulnerable and marginalised people, such as women and the poor. These groups are often left out of expert and some typical citizen surveys. These qualitative discussions are very similar to focus groups.
Workshops	Workshops usually involve a broad range of stakeholders who are willing to share information and discuss key issues. Workshops tend to be longer events than focus group discussions and feature more complex agendas. Workshops offer a good opportunity to share and extract information.

4.5 TARGETED SOCIETAL ASSESSMENTS

4.5.1 Aims of targeted societal assessments

The aims of targeted societal assessments include investigating the underlying causes of issues and concerns highlighted by stakeholders; verifying and augmenting the findings from earlier or ongoing studies; and develop a good understanding of the current status, drivers and trends in governance, institutional development, public and private expenditure, legislation, water services delivery and the wider political economy of the specified domain. The understanding gained should be sufficient to: 1) Contextualise, underpin and assist the interpretation of outputs from water accounting; 2) Identify opportunities for addressing water-related issues and concerns from a societal perspective; 3) Assess the scope for and potential benefits of doing things differently; and 4) Identifying potential barriers to reform and/or potential perverse outcomes (or externalities).

4.5.2 Analytical approach of societal assessments

This sourcebook recommends three different approaches to societal assessments, namely:

- governance assessment;
- political economy analysis;
- a combination of governance assessment and political economy analysis.

Reasons for proposing these three approaches include:

- They are well supported by information that can be downloaded at no charge from the Internet such as guidelines, case studies and research papers.
- They can incorporate or be used alongside other targeted societal assessments such as policy reviews, public expenditure reviews, livelihood analysis, gender audits, social audits, accountability assessment, reviews of legislation and regulatory frameworks.
- They can be adapted, targeted or used incrementally alongside biophysical assessments.

Societal assessments are, however, constantly evolving as lessons are learned and as new approaches are developed. It is notable that:

- **Disciplinary preferences exist:** For example, there is a tendency for more technically minded people to prefer governance assessments because they produce semi-quantitative information and they are somewhat less intrusive than political economy analysis. Political economist and social scientists tend to prefer political economy analysis.
- **Creative use of accessible information:** Experience is accumulating on the types of information that is useful and accessible to governance assessments and political economy analysis (Fritz *et al*., 2014).
- **Convergence is taking place:** Although there are still some fundamental differences between governance assessments and political economy analysis. There is increasing overlap in the methods and approaches that they use.

4.5.3 Water auditing: governance assessment

What is governance assessment?

Governance assessment is essentially a methodological approach that can be used for assessing governance in specified domains (OECD, 2009). Somewhat confusingly, thirteen different terms (in English) are used to describe governance assessment (OECD, 2009). This diversity of terminology is symptomatic of the fact that until recently, governance assessments were dominated by bilateral and multilateral donors and other external agencies (UNDP, 2009). The net result being that many agencies have been responsible for developing their own variants of governance assessment and governance assessment terminology.

While governance assessments vary according to the interests, needs and culture of the commissioning agency, a defining characteristic is that they attempt to measure current governance performance against a set of principles such as representation, accountability, transparency, responsiveness and so on. As a consequence, governance assessments tend to be based on gap analysis that starts with an idealised vision of what governance in a country, or another specified domain, should or could be (Harris *et al*., 2011). More recently, there has been a growing demand within countries for: 1) Assessments that are designed, implemented and owned by local stakeholders rather than an international agency; and 2) Information and evidence of progress against key governance indicators. Although the process of

BOX 4.6
Governance reform

- Governance reform is primarily a domestic affair. The implication is therefore that external agencies can facilitate or support governance reform processes but they should not drive it, impose it, lead it or manage it.
- Governance reform is most often a slow and long-term process spanning decades.
- It is often more realistic and pragmatic to seek and exploit opportunities for incremental progress rather than big leaps forward.

Source: EU, 2008

BOX 4.7
Typical governance assessment objectives

Governance assessments often have multiple objectives, including:

- **Comparing** the state of water governance in different countries by making use of cross-country data to raise awareness at the regional and global level and facilitate peer-to-peer learning.
- **Benchmarking** the performance of, for example, municipalities or water utilities and comparing one against another.
- **Diagnosing the nature and scope of an existing problem.** For example, integrity assessments can be used to assess the nature levels of water- related accountability problems.
- **Informing programming.** For example, informing, resource allocation, programme design and risk assessments at the programme level.
- **Reviewing and identifying trends and potential gaps** in policy-reform implementation in order to fine-tune or change a chosen reform path.
- **Monitoring** water sector performance and change over time (if repeated).
- **Bridging the supply and the demand side of governance** by providing entry points for civic engagement and empowering citizens to demand better delivery of services and accountability by decision-maker.

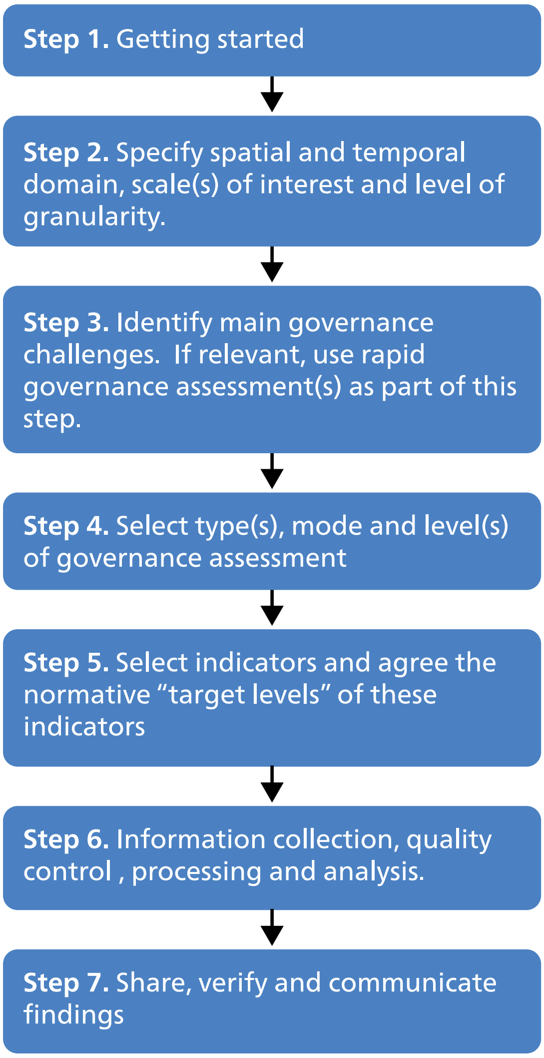
Source: UNDP, 2013

governance assessments are invariably politically sensitive, there are good reasons to believe that, when part of the national actor's agenda, country-led assessments are more likely to lead to real change in governance realities than, for example, an externally-led assessment (UNDP, 2009).

Governance assessment: principles and indicators

- Governance assessments focus on a set of governance principles and indicators for each principle[51]. Box 4.8 provides a set of governance principles and indicators that were developed by UNDP for a project in Mongolia (UNDP, 2009). Various approaches can be used to develop principles and indicators but, clearly, stakeholder engagement is advisable if the principles and indicators are to be accepted, owned and provide information that will be used by key stakeholders. It is also advisable to:
  - Select principles and indicators that align, as far as possible, with information that is being collected as part of water accounting.
  - Make use of indicators that are being used as part of national (or international) monitoring systems as this may reduce costs, make it possible to analyse trends over time and remove the need to pilot the indicator or sampling strategies.

FIGURE 4.2
Governance assessment: stepwise process



Governance assessment: stepwise process

Typically, a governance assessment involves the following steps[52] (see Figure 4.2):

Step 1: Getting started. Given that governance assessments are inherently political, a broad participation of stakeholders is advisable and desirable (UNDP, 2009). If relevant, a multi-stakeholder platform (MSP) should play a significant role in designing and implementing the governance assessment. Hence, a first step is often for the MSP to discuss and, if sufficient support is forthcoming, agree on roles and responsibilities for implementing the governance assessment. Often this task will be handed over to the water accounting and auditing implementation team.

Step 2: If relevant, specify the spatial and temporal domains. Typically the domains and scales of interest are specified earlier in

51 In this context, an indicator provides information on the state of the governance principle. To be useful, an indicator must be measurable at the scale of interest. However, it can be qualitative or quantitative and/or it can be based on perception or expert opinion. Whatever the type or nature of an indicator, it must provide information that is reliable and that stands up to scrutiny.

52 An alternative governance assessment stepwise process is described in UNDP (2013).

BOX 4.8
Governance reform

Participation:

- Women/men and poor/non-poor should enjoy and exercise the same rights to participate.
- Women/men and poor/non-poor should possess the capacities and resources to participate.
- An inclusive participatory culture should exist that encourages women and the poor to be active politically.

Representation:

- Parliamentarians at national and sub-national level articulate the concerns and priorities of women and the poor.
- Civil service is representative of social composition of the electorate, including women and the poor.

Accountability:

- Clear and effective lines of accountability (legal, financial, administrative and political) are necessary to safeguard judicial integrity, and to ensure honest and efficient performance by civil servants in the delivery of public services to women and low-income groups.

Transparency:

- Government decision-making in areas of particular concern to women and low-income groups should be open to legislative and public scrutiny.

Responsiveness:

- Accessibility of government to advocates of pro-poor, gender sensitive policy formation, implementation and service delivery.

Efficiency:

- Goods and services provided by the public sector at least in terms of cost and in the quantities/qualities desired by citizens.

Equity:

- The state redistributes entitlements through taxation and public expenditure in accordance with a democratically expressed social welfare function.

Source: Speed et al., 2013

the water auditing process. If for any reason this has not happened, domains and scales of interest should be specified before moving on to Step 3.

Step 3: Identify the main governance challenges. Ideally the MSP should take the lead in identifying and prioritising governance challenges and, as important, the institutional levels at which these challenges are most obvious or interesting.

If time and other resources permit, a rapid water audit, based on key-informant interviews, focus-group discussion analysis of secondary information, should help ensure that priority governance challenges are not overlooked[53].

[53] It is not expected that this step will identify and prioritise all governance challenges. However, outputs from this step should inform and provide a sound basis for: 1) Selection of the type, methods and levels of governance assessment and 2) Selection of indicators and setting the normative 'target levels' for each indicator.

Step 4: Select the type, methods and levels of governance assessment. This step should, as far as possible, be based on the needs of key stakeholders and priority challenges or opportunities that have been identified. Typically governance assessment use methodologies such as those listed in Table 4.1, for example, desk studies, key informant interviews and focus group discussions[54].

Step 5: Select governance indicators. Active participation of a wide group of key stakeholders in the selection of governance indicators has the potential of increasing the level of ownership of the governance assessment process and outputs (UNDP, 2009). However, the larger the group, the longer and more costly the process is likely to become. When it comes to finalizing the details, it is often best for the MSP to delegate this task to a smaller group. Box 4.9 is a typical check-list of questions that can be considered when identifying and selecting indicators Once indicators have been short-listed, it will be necessary to agree on the normative 'target level' of each indicator. Levels should correspond with an agreed vision of the desired level for each governance indicator in the specified country, sector or domains. This is easier if norms already exist for shortlisted indicators (e.g. as part of government

BOX 4.9

Selection of governance assessment indicators check-list

How one chooses to measure or assess an aspect of governance will directly impact the type of results that will be reported. Below is a check-list of questions to consider when selecting an existing or developing a new governance assessment indicator:

- Is the indicator suitable for gap analysis (i.e. assessing the gap between the current and desired level of governance)?
- Is the indicator linked in some way to an official norm (e.g. access to a certain level of water services)?
- Is the indicator politically sensitive? If yes, in what way?
- Does the indicator provide a direct measure or is it a proxy indicator?
- What sources of secondary information are available for this indicator?
- How can this indicator be measured or assessed?
- What will be derived from tracking/mapping this indicator?
- Can resulting information be easily aggregated or disaggregated?
- What form of governance is examined: de facto (i.e. what happens in practice) or de jure (i.e. existence of laws, regulations or a constitution)?
- Will the indicator provide qualitative or quantitative information?

Source: UNDP, 2009

[54] Additional governance assessment methodologies are listed and described in UNDP (2009) and Forresti *et al.* (2014).

policy or the manifesto of the ruling political party). If norms do not exist, it may be less contentious and less time consuming, to use a visioning process as a means of making a final selection of indicators and the desired or 'target-levels' of different indicators.

Step 6: Information collection, quality control, processing and analysis. The aim of this step is to produce outputs or findings that are:

- **Reliable** (i.e. the same or very similar findings should be produced if the assessment is repeated by another team).
- **Valid** (i.e. the indicators measure what they are supposed to measure).
- **Trusted** (i.e. key stakeholders have confidence in the methodologies used and in the outputs and findings).

Typically this step generates numerical information (e.g. scores against the different governance indicators) and significant amounts of qualitative information. The latter needs to be distilled into forms that help to contextualise and explain the reasons for the scoring in any given context. Typically processing and analysis of quantitative and qualitative information will include (after Cowling *et al.*, 2014):

- **Analysis governance scores:** This analysis can involve use of relevant statistics and presentation of outputs in tabular forms or spatially as maps. It is possible that cross-correlation of scores against different indicator may also generate useful and interesting findings.
- **Construction of timelines:** Key informant and/or focus groups are often good at constructing timelines that report changes in governance that they have experienced or witnessed. Comparing water timelines between contexts or geographic locations is often interesting.
- **Identifying dominant processes:** The spatial and temporal patterns of water-related problems may help identify possible causes. However additional evidence may be needed before causalities can be attributed.
- **Identification of outcomes:** For example identifying potential outcomes by comparing governance scores with information on the water services levels of different water users and uses.
- **Use visualisations:** Present information in forms and formats (e.g. infographics) that go beyond traditional spreadsheets, graphs or bar charts by encouraging stakeholder to explore the information presented.
- **Note the unexpected:** Unexpected patterns or values are often caused by errors in the data collection of the analysis. However they may also flag something that is both interesting and important.

Step 7: Share, verify and communicate findings: Ideally the MSP will hold regular meetings while a governance assessment is being implemented. During these meetings preliminary findings should be presented, discussed and, if and when relevant, verified. Such meetings should also guarantee that government and non-governments stakeholders are aware of the process and have regular opportunities to comment both on the process and the findings. The multi-stakeholder platform can and should also take a leading role in communicating findings to a wider audience.

4.5.4 Water auditing: political economy analysis[55]

What is political economy analysis?

As defined by the OECD, political economy analysis (PEA) is concerned with the interaction of political and economic processes in a society: the distribution of power and wealth between different groups and individuals, and the processes that create, sustain and transform these relationships over time. More specifically PEA investigates and analyses the incentives, relationships, distribution and contestation of power between different groups and individuals (Mcloughlin, 2014). The rationale being that this type of analysis can support more effective and politically feasible sectoral and inter-sectoral strategies, as well as more realistic expectations of what can be achieved, over a range of timescales (Copestake and Williams, 2012).

In practical terms the utility of PEA depends on the extent to which its findings and recommendations influence policies, attitudes, practices and outcomes of strategies. The assumption here is that, by embedding PEA in water accounting and auditing, PEA can play a significant role in identifying: 1) Underlying causes of many water related problems; 2) Opportunities for overcoming barriers to policy reform; 3) Strategies for mitigating the risks that are inherent in all reform processes (e.g. lack of commitment by key stakeholders); and 4) More realistic expectations of what can be achieved by projects and programmes that attempt to instigate change in the water sector (DFID, 2009).

Often specialists have a tendency to dispense advice on what should be done without adequately considering the constraints and opportunities created by the prevailing political environment. PEA encourages deliverers and users of water-related advice to consider the political feasibility of this advice prompting or contributing to desired outcomes. As important, PEA provides a means of anticipating political, social and cultural challenges to sector reform (see Box 4.10) and, when or where relevant, identifying and proposing necessary changes to recommendations and the formulation of the sector reform programme.

What are the distinguishing features of PEA?

A distinguishing feature of PEA is that it goes beyond interesting contextual analysis to looking creatively at constraints on, or opportunities for change and, in many cases, the possibility for building on what already exists rather than trying to create something new (Duncan and Williams, 2010). PEA is also distinguised by (After Duncan and Wiliams, 2010):

- **An emphasis on the centrality of politics.** More specifically, PEA focuses on how political power is secured, exercised and contested and assumes that the insights gained will explain how, where and why decisions and actions are taken (or not taken).
- **Less attention to norms.** The starting point of PEA is to try to understand country, region or sectoral realities. This contrasts with the more conventional approach in governance assessment of defining a norm and seeking to understand why a country, region or sector deviates from this norm.
- **Specific attention to factors that shape the political process.** Political economy approaches try to place current realities in the context of a country's history, society, culture and geography. Consideration is also to be given to macro-politics

[55] There has been a tendency in recent years to differentiate between standard PEA and problem-driven PEA. The view taken in this sourcebook is that PEA (like water accounting) should, in almost all cases, be driven or focused on problems, concerns or issues in the specified domains not least because this helps ensure active engagement of key stakeholders.

BOX 4.10
Recurring challenges in sector reform programmes

Typical challenges faced by sector reform programmes include:

- **Lack of political will or broad leadership support for change.** In many situations this is lacking and the reform process relies heavily on a lone champion who may or may not survive or, as is often the case, if he or she does not have enough political support to actually see the reforms implemented.
- **Resistance from middle managers or the professional bureaucracy.** Resistance from this intermediate level can be passive or aggressive but experience has shown that these middle managers can be the 'layer of clay' through which nothing passes.
- **Vested interests.** These are special interest groups opposed to reform. The effect that they can have on a reform process depends on how motivated they are and how quickly and effectively they mobilise opposition to reform.
- **Hostile public opinion**. Many reforms are opposed by public opinion even if they are in the broader national interest. The media often plays a critical role in influencing public opinion either for or against reform.
- **Silent majority**. Millions of potential beneficiaries from a reform are not organized nor are they aware of what they stand to gain. In contrast to those with vested interests who are often a minority that is acutely aware of what is at stake.
- **Citizen demand for accountability.** Social accountability is often part of reform design. The idea being to engage citizen action to monitor official performance and sanction bad governance. Getting this to happen is far from easy as a result of inertia, lack of awareness, fear of reprisal or more important things to do.

Source: *CommGap, 2009a*

and external factors that might influence the political process in a specified country, region or sector.

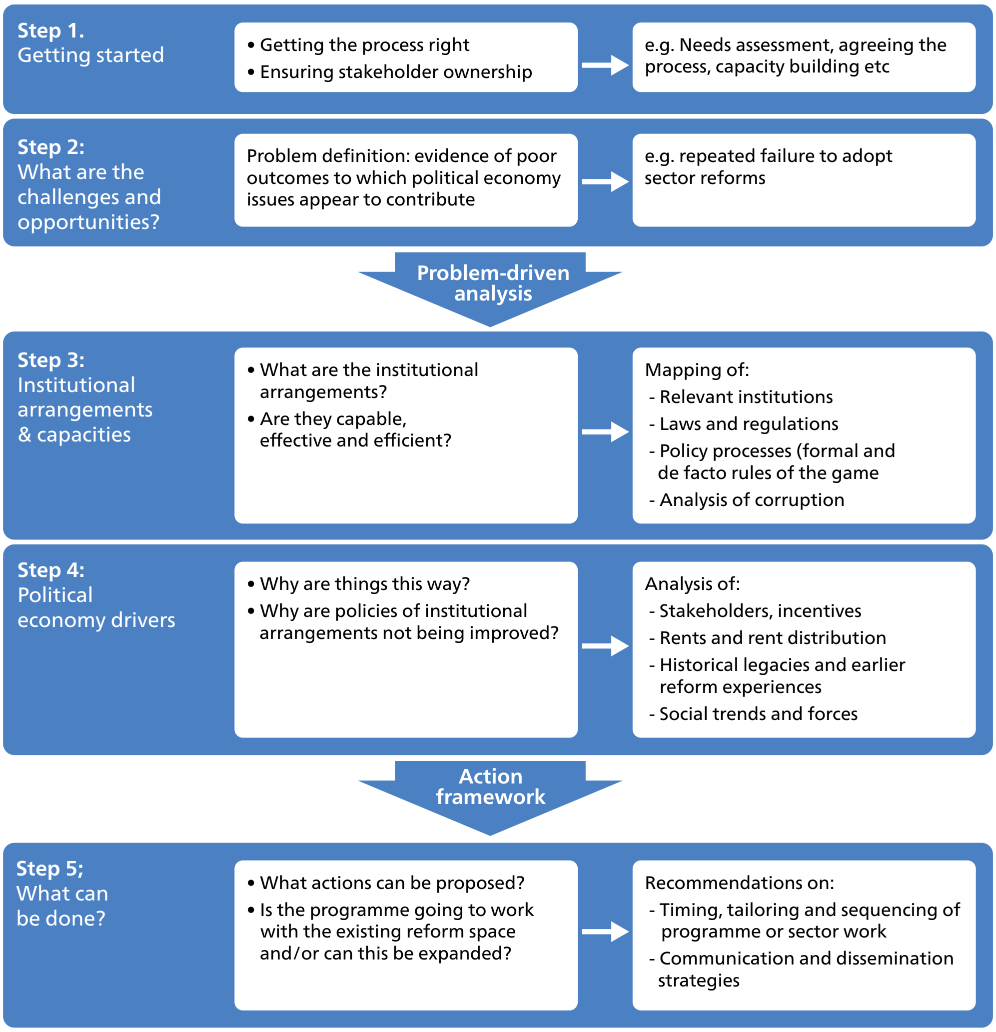
- **A focus on institutions:** Institutions play a crucial role in determining the incentive frameworks that induce patterns of behaviour. Strong leadership and reform champions can play important roles as change agents, but in general it is difficult for individuals to bring about lasting change without broad support.
- **Recognition that development agencies are political actors:** Development agencies are explicitly examined as politically influential players with their own geostrategic, commercial and developmental objectives. The very fact of their providing resources to selected beneficiaries changes the dynamics of political contestation.

BOX 4.11
Problem-driven PEA

An important lesson learned is that for PEA to be of practical use – whether applied at the country or the sector level – it needs to start with a diagnosis of a particular, unresolved development challenge or the assessment of a specific opportunity to be seized. This approach to using PEA is more likely to identify actionable recommendations.

Source: CommGap, 2009a

FIGURE 4.3
Political economy analysis: stepwise process



Source: World Bank, 2011

- **A focus on eliciting information that is shared and trusted.** While PEA is not hard science (DFID, 2009), guarantees of rigour and objectivity, as far as possible, are important if information and evidence is to stand up to the scrutiny of key stakeholders. One key principle is the importance of triangulating data and findings by drawing on as many independent (or semi-independent) sources as possible.

What are the main elements of political economy analysis?

At the core of PEA is a set of well-proven methods and tools (e.g. stakeholder analysis, focus-group discussions, key informant interviews, drivers of change studies, power analysis, institutional mapping, accountability assessment and so on) most of which will be familiar to anyone who has worked on development or sector reform-related programmes. When used systematically, these methods and tools can generate answers to questions such as those listed in Box 4.12. The aim being not only to assess the scale, nature and effects of specific problems but also to identify the drivers that explain why the problem exists and to examine what can be done to address specific problems.

BOX 4.12
Checklist of typical questions for use as in sector-level political economy analysis

Roles and responsibilities: Who are the key stakeholders in the sector? What are the formal or informal roles and mandates of different players? What is the balance between central/local authorities in provision of services?

Ownership structure and financing: What is the balance between public and private ownership? How is the sector financed (e.g. public or private partnerships, user fees, taxes, donor support)?

Power relations: To what extent is power vested in the hands of specific individuals/groups? How do different interest groups outside government (e.g. private sector, NGOs, consumer groups, the media) seek to influence policy?

Historical legacies: What is the past history of the sector, including previous reform initiatives? How does this influence current stakeholders' perceptions?

Corruption and rent-seeking: Is there significant corruption and rent-seeking in the sector? Where is this most prevalent (e.g. at point of delivery; procurement; allocation of jobs)? Who benefits most from this? How is patronage being used?

Service delivery: Who are the primary beneficiaries of service-delivery? Are particular social, regional or ethnic groups included or excluded? Are subsidies provided and which groups benefit most from these?

Ideologies and values: What are the dominant ideologies and values that shape views around the sector? To what extent may these serve to constrain change?

Decision-making: How are decisions made within the sector? Who is party to these decision-making processes?

Implementation issues: Once made, are decisions implemented? Where are the key bottlenecks in the system? Is failure to implement the result a lack of capacity or other reasons related to the political economy?

Potential for reform: Who are likely to be the 'winners' and 'losers' from particular reforms? Are there any key reform champions within the sector? Who is likely to resist reforms and why? Are there 'second best' reforms that might overcome this opposition?

Source: DFID, 2009

Political economy analysis: stepwise process

PEA should be viewed as a dynamic process (DFID, 2009). The success of which is measured not by the conduct of the analysis but by the extent to which findings contribute to desired outcomes (e.g. reduced groundwater overdraft, more equitable access to water services). Typically political economy analysis involves the following five steps (see Figure 4.3):

Step 1: Getting started. The aims of this step include ensuring that: 1) Key stakeholders have a high level of ownership of the process; and 2) The necessary resources and capacity are available. The checklist in Box 4.13 can be used to ensure that key process issues have been taken into account.

BOX 4.13

PEA 'Getting Started' check list of questions

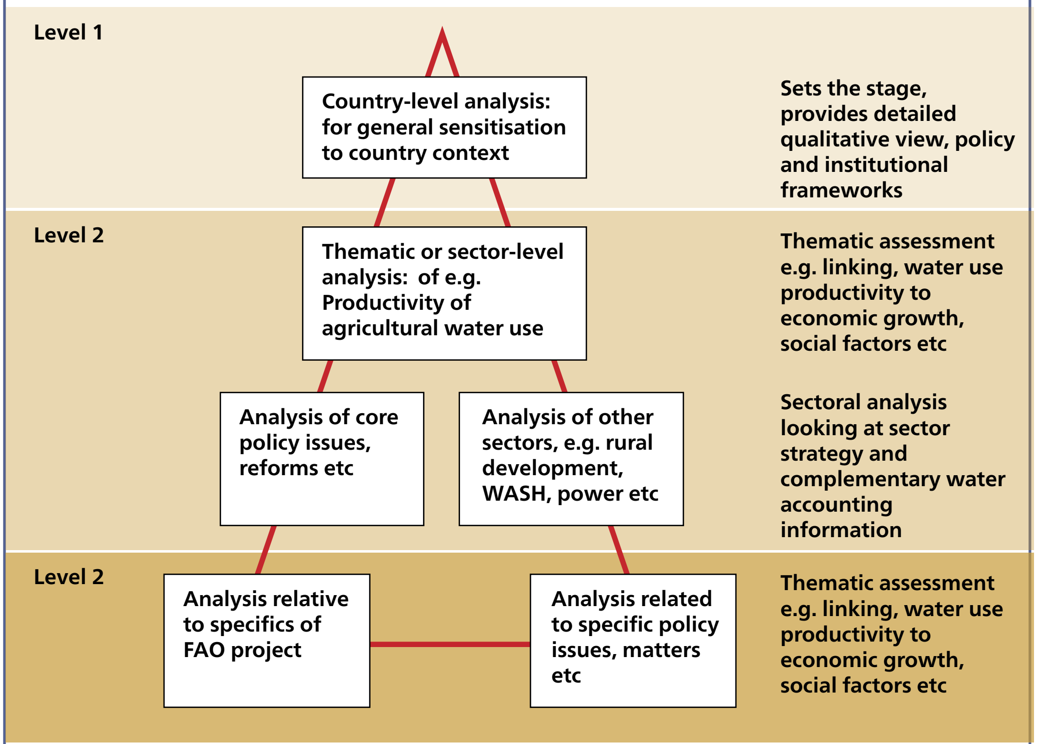
- What is the purpose of the political economy analysis?
- Is the timing right to feed into strategy, planning, reviews or other decisions?
- Is the length of the process proportionate?
- Who are the key stakeholders? Are there tensions between different stakeholders, and how can these be managed?
- Is there sufficient internal commitment to the importance of the analysis and its value for strategy development and similar?
- Is there a clear owner or champion with responsibility for taking the analysis forward and disseminating the findings?
- What mix of skills and expertise are required to undertake the work? Will it be conducted in-house, or are specialist consultant skills required?
- What methodology and data collection techniques are to be used?
- Are the right partners (e.g. research organizations, private sector, etc.) involved in the analysis to ensure it is robust and rigorous?
- What mechanisms are necessary to help broaden participation in the process?
- Has it been agreed how the work will be disseminated, and to whom? Do different products need to be created for different audiences?
- Is there an agreed process for follow-up once the analysis is complete?
- Have indicators been developed to assess the impact of the analysis on existing programmes and processes?
- What results are expected from the work?

Step 2: Identify challenges and opportunities. Initial identification of challenges and opportunities may emerge from stakeholder dialogue; review of earlier studies; review of secondary information; and/or rapid political economy analysis of existing or ongoing policies, research studies or pilots. This step also involves making choices on the institutional levels of the analysis and specifying the boundaries of the domain of interest. Typically three levels are used, but, depending on a needs assessment, fewer or additional levels may be considered. Typical levels are (see Figure 4.4):

- **Level 1: Country-level analysis** aims to identify and assess the overall governance situation and the main political economy drivers. Analysis at this level tries to capture important factors, such as the geo-political context, important social divisions and various socio-cultural factors and how these have evolved over time (including the impact of past legacies on the current political and economic landscape), and the evolution of the political management of economic rents[56] (World Bank, 2009).
- **Level 2: Sector or thematic level analysis** focuses on an entire sector, selected issues within a sector or a specific theme. This analysis complements and supplements the outputs from water accounting by, for example, focusing on the

[56] Rent and rent-seeking refer to income generated by privileged access to a resource or politically created monopoly rather than productive activity in a competitive market. Some political systems revolve around the creation and allocation of such incomes – hence 'rent-seeking'.

FIGURE 4.4
Typical levels of political economy analysis



Source: World Bank 2011

governance and wider political economy of, for example sustainable management of water sources, cost-effective operation of water supply infrastructure; and equitable delivery or access to water services.

- **Level 3: Problem-driven analysis** focuses on specific projects or programmes or priority problems or opportunities that have been identified by key stakeholders or by a rapid water audit. Typically, this analysis tries to generate advice on how to tackle these problems but often this is not possible without Level 1 and Level 2 analysis.

Step 3: Agree institutional arrangements. This is a critical step in PEA in part because decisions taken during this step will have a major bearing on whether the process and the findings are: 1) Owned and appreciated by key stakeholders; 2) Regarded as an imposition that has been foisted upon them by local activists or an external agency; or 3) Are decisions ignored as being of no value or relevance.

Part of the rationale underpinning this sourcebook is that key stakeholders are more likely to engage actively in PEA if they are involved in the process from the outset and if it is an integral part of water accounting and auditing rather than a stand-alone activity.

In most cases, instigators or champions of political economy analysis have to strike a balance between active engagement of key stakeholders and a completely unrestricted process. The alternatives, at two ends of a continuum, are to have: 1) Active engagement of all key stakeholders but so many restrictions (or no-go areas) that the process has no depth, value or substance; or 2) Limited or even no stakeholder engagement but no

BOX 4.14

Challenge of information acquisition

It is important to recognize that detailed evidencing of problem-driven governance and political economy diagnostics can be challenging. Pertinent data or information is not routinely collected by sources such as a country's national statistical office or ministry of Finance, or by international agencies. In addition, there may be issues with the accessibility of relevant data. Evidencing can be particularly challenging for sector-focused and thematic analysis. For country-level analysis, a greater amount of relevant information is often available through the national press or previously published analysis. It is also important to recognize that even when pertinent information is available, it may not be trusted or accepted by key stakeholders and, in some cases, the veracity of information may be contested by different stakeholders.

Source: World Bank, 2009

restrictions on a process that produces in-depth findings that are ignored or rejected by key stakeholders.

In some cases, it may be that stakeholders agree to several cycles of PEA that starts with mapping institutions that have a relatively low political sensitivity or risk and moves progressively to mapping practices that have a higher political sensitivity or risk (e.g. accountability assessment). The aim of each cycle is to build confidence in the process and to incrementally 'raise the bar' with regard to issues that can be addressed and discussed in open meetings.

Step 3 also involves identifying and agreeing the purposes of the PEA. PEA can be conducted for a number of different purposes, for example it can increase internal understanding, inform programming, influence policy dialogue and identify the reasons reform programmes are not resulting in the desired outcomes (After DFID, 2009). Responsibility for carrying out the PEA can remain with a multi-stakeholder platform or passed to the water accounting and auditing team[57]. Either way, it is very important to agree on this at the outset because these institutional arrangements will heavily influence how the analysis will be conducted, the resources required, communication of findings and any follow-up.

By the end of this step, the following should have been agreed:

- Institutional arrangements for implementing the PEA (e.g. the extent to which the process is owned and implemented by key stakeholders or contracted out).
- Any major restrictions on the process, including access to information, and what can be analysed. Alternatively a cyclical process PEA, as described above, may be agreed.
- The purpose of the PEA.
- Need for specialist inputs or capacity-building.
- Initial mapping of, for example, relevant institutions, laws and regulations,

[57] Note that the water accounting and auditing implementation team can comprise of government staff or task of assembling and managing an implementation team can be contracted out.

policy processes and accountability procedures.

> BOX 4.15
> **Capturing historical legacies**
>
> Historical legacies often have profound influence on the dynamics of the political economy of a specified domain. Gaining insights into the nature of these legacies and how societies continue to deal with them, provides depth and perspective to the issue of 'how things have become the way they are today'
>
> *Source:: World Bank, 2009*

Step 4: Governance and political economy analysis. Mapping and analysis of institutions is widely considered to be a core part of the broader political economy analysis. This said, many studies map and analyse institutions without considering underlying political economy drivers (e.g. stakeholder power relations, rent distribution, historical legacies, path dependency and political history) that explain why things are as they are (World Bank, 2011). Moreover, political economy analysis is often predominantly focused on analysis of stakeholders (e.g. who the players are) without a sufficient understanding of, for example: 1) Broader political economy drivers or the institutional context in which they operate; and 2) Interactions between formal and informal institutions and stakeholders.

Step 4 involves in-depth analysis that aims to drill down to the underlying reasons why things do or do not happen. Typically, the methods used will include those listed in Table 4.1 or more specialist PEA tools[58]. Step 4 also involves careful consideration of the evidence that has been collected and analysed. Credible political economy analysis needs to be supported by solid evidence and a compelling 'analytic narrative' consistent with experience and systematically gathered data and information, while avoiding the pitfall of technical analysis of only easily-accessible information combined with some broad statements about governance and political economy (World Bank, 2009).

Step 5: Way forward. The fifth step is to identify and assess governance and policy options in terms of the likely reform space and steps that can be taken to improve the likelihood of adoption and impact. These recommendations can also clarify which technically feasible policy options and approaches may be politically acceptable and feasible in the specific context or domain. In many cases, recommendations should be assessed and/or tested against a range of scenarios. There is also merit in presenting a menu of options rather than offering or prescribing a single solution even if this is an aggregate of many components (World Bank, 2011).

As will be discussed in Section 6.3, effective communication of findings and recommendations to all stakeholders is also crucially important. In particular, communication strategies must recognize that water auditing findings, outputs and recommendations may be rejected if they challenge accepted wisdom, cultural values and sanctioned discourses.

4.5.5 Water auditing: combined approach

What is the combined approach?

The approach of governance assessments is based on quantifying the gap between the current level of governance and a desired normative level of governance. In contrast, PEA takes the current governance and political economy in a specified country, sector or domain as the starting point for analysis. The combined approach, as the name suggests, is a combination of two approaches. In the case of the World Bank's

[58] For more information on PEA methods and tools see http://www.gsdrc.org/docs/open/PEA.pdf

combined approach, the ultimate objective and motivation is to develop more viable approaches to reforms and, more specifically to enhance the effectiveness of the reform programmes that they fund (World Bank, 2009).

By combining governance assessment and PEA, it is possible to mitigate, in part at least, stakeholder concerns over the intrusiveness of this type of study without unduly compromising the quality and depth of findings that are generated. It can be argued also that the combined approach can easily be tailored to complement and add value to a water accounting and auditing process in most societal and biophysical contexts. It is simply a matter of picking, choosing and blending the appropriate elements of each approach.

When should the combined approach be used?

The combined approach should be used in situations when it is likely to produce better outcomes than using governance assessment or political economy analysis on their own. These include situations in which an initial cycle of water auditing is based on a country-led governance assessment. In addition to providing important information, this first cycle is used to generate interest from and gain the confidence of key stakeholders. Once this is achieved, subsequent water auditing cycles can be based on cycles of PEA. However, concerns over the sensitivity of PEAs can be exaggerated and, depending on the context, potential sensitivity can be defused in a number of ways that range from the language used to sharing of key insights and messages in briefings with a range of stakeholders rather than sharing of all the underlying detail (Fritz *et al*., 2014).

4.6 THINKING POLITICALLY, WORKING DIFFERENTLY

4.6.1 Aims of thinking politically, working differently

While there is a broad acceptance that politics really matter, the default response to most water-related issues and concerns tends to be technical in nature (After Unsworth 2009, and Rocha Mendocal, 2014). In the context of water accounting and auditing, the main aim of 'thinking politically' is to rectify this situation by encouraging stakeholders and members of multi-stakeholder platforms to take a more balanced approach when responding to water related concerns and issues.

While PEA and governance assessments are useful analytical tools that can generate evidenced societal understanding and insights at different institutional levels, they are not meant to do more or less than this. Or put another way, they are unlikely to provide quick fixes or readymade answers to what are often complex problems[59]. As a result, many of the organizations that have been promoting and using PEA and governance assessments are moving away from just 'thinking politically' to also 'working differently'. In practical terms this can be achieved by using cycles of water accounting and auditing to support for example, action research, problem-driven iterative adaption and stakeholder dialogue and concerted action (SDCA)[60] [61]

[59] Particularly in areas of increasing water scarcity, many water-related problems may be classed as 'wicked problems' (see e.g. Baties, 2008)

[60] See Andrews *et al*. (2013), Rao (2014) and Moriarty *et al*. (2010).

[61] See Rao, S. 2014. Problem-driven iterative approaches and wider governance reform. GSDRC

4.6.2 Practical approach to thinking politically, working differently

Rationale

The underlying rationale for adopting 'thinking politically, working differently' that is supported by water accounting and accounting is based on the following:

- There is an important political dimension to all societal aspects of water resource management and water services delivery systems (e.g. governance, institutions, finance, legislation and the broader political economy).
- Water accounting and auditing provides a balanced approach to: 1) Analysing priority issues and concerns in the specified domains from both biophysical and societal perspectives; and 2) Evaluating opportunities for addressing these concerns and issues that may be biophysical, societal or a mix of both.
- Water accounting and auditing aims to work differently by: 1) Engaging actively with stakeholders; 2) Being problem focused or driven; 3) Adopting an evidence-based or informed approach; 4) Taking an integrated approach that is relevant and well matched to different biophysical and societal contexts; 5) Working iteratively towards understanding the causes of issues and concerns and identifying opportunities for addressing these causes; and 6) Supporting reform or change processes that are incremental and based on social and institutional learning.

Stakeholder engagement

The approach to water accounting and auditing recommended in this sourcebook is based on a stakeholder engagement (see Section 2 on Inception activities and stakeholder engagement) and, more specifically organizing and facilitating appropriate forms of multi-stakeholder platform. In most cases, the benefits of engaging actively with stakeholders during a water accounting and auditing programme easily outweigh the added complications. However, active stakeholder engagement is not a panacea, especially in areas that are experiencing increased competition for limited water resources (see Box 4.16).

Problem focused (or driven)

Water accounting and auditing programmes tend to be problem focused, because this is a more efficient way of working (i.e. resources are concentrated where they are most needed rather than being spread thinly) and because stakeholders are more likely to engage actively if the programme focuses on issues and concerns that they have identified and prioritised. However, water accounting and auditing programmes must gain a good understanding of the dominant biophysical and societal processes and feedback mechanisms in a specified domain so that the issues and concerns can be contextualised and appropriate approaches to modelling selected and used.

Evidence based (or informed)

It is a well-known fact that decision-making in the water sector is often based on a combination of specialist advice (often not supported by evidence), intuition, assumptions and guesswork. In addition, the need for making decisions is circumvented by adopting a 'one size fits all' or 'business as usual' approach. Either way, an important assumption in this sourcebook is that major improvements in water sector performance can be generated by basing decisions on the 'best-available' information, evidence and analysis, owned and internalised as part of a water accounting and auditing programme.

BOX 4.16

Some key differences between integrated approaches to water management under different water scarcity conditions

Relatively low water scarcity	Relatively high water scarcity
Bias towards using uni-sectoral approaches to solving problems	Bias towards using multi-sectoral approaches to solving problems
Multi-sectoral integration needed to tackle challenges that include: pollution, flooding, environmental sustainability, climate change, biodiversity protection and cost efficiency of services delivery	Multi-sectoral integration needed to tackle additional challenges that include: Managing competing demands for water, equitable services delivery, conflict resolution, maintaining water security during droughts
Relatively easy to achieve consensus using multi-stakeholder processes	Relatively difficult, if not impossible, to achieve consensus using multi-stakeholder processes
Possibility of win-win solutions to some challenges	Few win-wins available. Most solutions have significant negative trade-offs or externalities

Integrated approaches

Water accounting and auditing programmes invariably take a holistic integrated approach. In part because responsibilities for managing water resources and delivering water services are split across different line departments (e.g. water resources, rural development, public health engineering, irrigation, planning, local government and so on). However implementing holistic integrated approaches to managing water, land and other natural resources management is politically challenging and not necessarily desirable in all contexts (e.g. in areas that are well endowed with water resources). It is also important to recognize that there are different types or levels of integration (see Box 4.17). Some types of integration are uni-sectoral and can be handled very well within the water sector or within individual water-sector line departments (e.g. integrated management of surface and groundwater or integrated delivery of water services to different users and uses). Others types of integration are inter-sectoral and necessitate the water sector working cohesively with other sectors (e.g. with the agriculture, local government, power sectors).

Iterative and incremental

The approach to water accounting and auditing recommended here is based on cycles of information acquisition, analysis and learning. As a consequence, it complements approaches that also take incremental and adaptive methods for piloting new processes that work with and build the capacity of existing institutions[62].

The World Bank (2009) combined approach to governance assessment and PEA is based on the recognition that, particularly, in reform processes, 'best is (often) the enemy of good'[63]. Although a 'best' solution, whether biophysical or societal, may be superior to a 'good' solution from an academic perspective, this advantage can easily be lost or even reversed under real-world conditions if the solution is only

[62] Merrey and Cook (2012). Fostering institutional creativity at multiple levels: towards facilitated institutional bricolage. Water Alternatives 5(1): 1-19 and Andrews, Matt. 2013. The limits of institution reform in development. Cambridge Press.

[63] The meaning of this aphorism or proverb is that, by striving for perfection in, for example, governance, the net result can often be no improvement at all. The phrase is commonly attributed to Voltaire whose poem, La Bégueule, starts "Dans ses écrits, un sage Italien dit que le mieux est l'ennemi du bien".

BOX 4.17
Different types or levels of integration

- **Vertical inter-sectoral integration:** e.g. nested planning across institutional levels and biophysical scales involving different line departments and other stakeholders.
- **Horizontal inter-sectoral integration:** e.g. stakeholder dialogue and concerted action at one institutional level that involves, say, the water, energy and agriculture sectors.
- **Uni-sectoral integration:** e.g. integrated planning management of water services delivery systems for a range of water uses or users.
- **Integration along value or supply chains:** e.g. mapping and managing water use and productivity from the 'field to the fork'.
- **Trans-boundary integration:** e.g. river basin organizations or initiatives involving riparian countries.
- **Integrated assessments or monitoring systems:** e.g. use of water accounting and auditing to monitor biophysical and societal trends in water supply, demand and services delivery.
- **Multi-stakeholder learning processes:** e.g. communities of practice, learning alliances, quality improvement collaboratives.

Source:: World Bank, 2009

partially implemented, or if it stalls or if it is rejected because it is politically or socially unacceptable. There is also the risk that a 'best' solution may trigger unintended consequences during implementation. In contrast, 'good enough governance' captures the notion of focusing on priorities and improvements that are feasible, affordable and acceptable to key stakeholders rather than trying to reform governance wholesale (Grindle, 2007).

However, the concept of 'good enough' does not imply or necessitate the abandonment of 'good governance' as a principle. Rather, it acknowledges that under real-world conditions: 1) Not all desirable governance improvements are affordable or feasible in the short to medium term; and 2) Feasible, incremental improvements may have tangible payoffs in terms of improved outcomes and increased commitment to the reform process of stakeholders. Overambitious, vague or abstract governance reforms are unlikely to be effective or sustainable (EU, 2008) and the initial focus should be getting the basics right (see Box 4.18).

Finding feasible approaches to reform may include prioritising the vulnerabilities or concerns that can be addressed with a reasonable chance of success by proposing governance arrangements that can be improved in ways that: 1) Have a high level of support from some if not all key stakeholders; 2) Are logical and easy to understand (rather than abstract); 3) Have the potential of lessening the political economy constraints, for example by supporting coalitions for change, promoting better-informed public debate, and so on.

BOX 4.18
'Basics first' in sector governance: what does it mean?

In the broader context of sector governance a basic first approach implies:

- Strengthening emerging domestically-rooted demands for governance and accountability – rather than focusing only on the supply side of governance.
- Seeking to formalise informal governance practices gradually – rather than attempting to replace them by formal approaches in one strike.
- Working on increasing predictability and gradually reducing discretionary behaviour – before introducing comprehensive and integrated planning and monitoring systems.
- Increasing basic transparency in governance, targeted directly to those with a clear interest in the matter – rather than 'putting everything on the web.
- 'Clarifying' public budgets and help various actors to engage in budget processes related to the sector.
- Working on governance and accountability for inputs and procedures before making managers accountable for results (manage for results rather than by results).
- Strengthening external controls before relying on managerial accountability.
- Adding merit as a criterion when selection is based on loyalty and patronage – rather than seeking to replace loyalty-based recruitment with merit-based.
- Monitoring sector performance (e.g. in health) by focusing on practical, down-to-earth issues (e.g. absenteeism, informal payments).

Source:EU, 2008

4.7 TIPS AND TRICKS

- Water auditing core teams must develop and maintain a culture of rigorous collection, quality control and interpretation of information and evidence if outputs and recommendations are to stand up to scrutiny.
- Every attempt should be made to remove biases by using appropriate well-designed investigative procedures (e.g. having a proper sampling frame; scrupulous adherence to good investigative and information management practices).
- Although it may be perceived as being an extra expense, hiring trained facilitators for formal meetings often works out to be good value for money.
- A large number of helpful tips related to collecting, reviewing and analysing secondary data can be found in Care (2005).
- Guidance on combining and making good use of qualitative and quantitative information can be found in World Bank (2007).

5. INFORMATION MANAGEMENT AND INTEGRATED ANALYSIS

5.1 AIMS OF THIS SECTION

Up until this point in the water accounting and auditing process, water accounting and auditing activities have been carried out at the same time as a few crosscutting activities (see Figure 1.3. Overall approach to water accounting and auditing). Emphasis was placed on the biophysical and societal perspectives: 1) Building evidence-informed understanding of the specified domains; 2) Identifying underlying causes of problems, issues or concerns; and 3) Making a preliminary assessment of opportunities to address problems, issues and concerns. From now on the emphasis of the water accounting and auditing process is on cycles of integrated analysis of biophysical and societal information and collected evidence.

Typically water accounting and auditing involves acquisition, processing, quality controlling, analysis, interpretation and sharing of large amounts of data and information[64]. Resources and information management skills are also needed to make sure that the resulting information is stored and made available when and where it is required and in the forms and formats that meet the needs of the relevant specialists, stakeholders and other users. It is crucial that sufficient metadata is collected and made available so that users can make sense of the information and make informed judgements on its usefulness or relevance.

BOX 5.1

Information management principles

- **Make maximum use of existing information bases or systems** because this will provide information on trends but check the quality of the information before using it.
- **Make maximum use of relevant published or grey material** but always with caution.
- **Aim to establish or create information bases or systems that are shared and accessible to all stakeholders**, with the aim of reducing: 1) Inter-sectoral inter-stakeholder disputes over the veracity of the information; and 2) Reducing asymmetries in access to information.
- **Give more weight to verifiable observations and empirical information** because the uncertainties in modelled or meta information may be large or difficult to estimate.
- **Elicit information from local stakeholders but be wary of myths and guesswork.** As a general rule, the observations of local stakeholders will be more reliable than their opinions about the causes of problems. Often the latter are based on myths or guesswork.

[64] The terms data and information are interrelated and often used interchangeably. In general, data refers to raw facts, figures and observations in different forms and formats. While information refers to data that has been processed or analysed in ways that make it meaningful and useful to whomever it is used by or accessed.

BOX 5.2
A few definitions of modelling

In the context of water accounting and auditing:

A *model* is a representation of a biophysical and/or societal system through the use of mathematical equations and algorithms.

A *modelling system* is a computer program or software package that is typically built around a model (or number of models); can access input data (e.g. from a database); can generate output in different forms and formats (e.g. as a map, a table or a probability distribution) and has a user interface with a number of models and input and output systems to facilitate application.

A *model application* is the use of a model or models to address defined questions (e.g. what if questions) and to generate outputs (e.g. estimates of river flows in an ungauged catchment, estimates of the marginal benefits of specified water use in space and time).

A key aim of information management is to make information available for integrated analysis that includes: 1) Scenario building and analysis; 2) 'What if' and 'What's best' modelling; and 3) Development and evaluation of strategies that have the potential of addressing and resolving priority issues and concerns in the specified domain.

This section emphasises the importance of: 1) Subjecting all the data and information to some level of quality control; 2) Making appropriate use of new and evolving information technologies; and 3) Acquiring information from as many independent sources as possible, as this will aid triangulation and other quality control procedures. In addition, this section discusses the: 1) Role of modelling in water accounting and auditing; 2) Types of models that are available; 3) Selection of appropriate models; and 4) The process of setting up and using models and modelling. Although the focus is on the selection and application of well-proven hydrological models, the potential benefits of using hydro-economic and integrated approaches to modelling are also highlighted.

The section goes on to describe a scenario-based approach to strategy development. This approach seeks to combine the opportunities that have already been assessed, into coherent strategies that could achieve a range of objectives (i.e. a vision) across a differing scenarios. Strategies are evaluated, scrutinised and tested by using a combination of inter-disciplinary analysis, modelling and stakeholder dialogue.

Finally the section highlights the sources of uncertainty that are typical in water accounting and auditing processes, and draws attention to the approaches that can be used to estimate and mitigate uncertainty.

5.2 INFORMATION MANAGEMENT

5.2.1 Information sharing

Accessing good-quality secondary information is often a challenge. In an ideal world, stakeholders would be willing to share information by making it readily available from open-access databases. The reality in many countries is that holders of information are unwilling to share this information, other than among a small number of users who can be trusted not to share it with anyone else. The reasons for this may be political, social or commercial. In some cases, unwillingness to share information is driven by a desire to sell information or to maintain a competitive advantage over other individuals or organizations that do not have access to the information.

One approach to improving information sharing centres on having all interested parties use the same centralised platform. The alternative to this centralisation of information, or unification of working environments, is to develop standard ways to encode, transmit and process data and to make distributed data sets interoperable and shareable. However, these 'technical' fixes will not necessarily overcome a deep-seated culture of not sharing information.

More positively, the number of open-access global and regional information bases is increasing rapidly. If this trend continues, online open-access information sources are likely to become increasingly important sources of information for water accounting and auditing. It is notable also that the increasing availability of cloud-storage services such as Dropbox has reduced the costs and made it much easier to share information.

5.2.2 Objectives of information management

Experience has shown that effective information management is crucial if water accounting and auditing is to achieve objectives that include:

- Information of an acceptable quality is available to stakeholders and specialists as and when it is required.
- Well-informed dialogue between stakeholders and specialists at any given institutional level and between institutional levels.
- All stakeholders have access to and use the same shared or common information base during stakeholder dialogue (e.g. as part of inter-sectoral planning).
- If relevant, the content of a shared information base is well balanced and has similar or compatible levels of scale, reliability and precision across all the elements.
- Risks of asymmetrical access to information among stakeholders are minimised.
- As far as possible, information is uncontested by stakeholders or specialists.
- Biophysical and societal information is geo-referenced so that it can be mapped or subjected to interdisciplinary spatial analysis.
- If relevant, information is updated ideally by monitoring systems or programmes that are well managed and have long-term financial support.
- Raw data are not mixed with simulated data (without this being noted in the metadata).
- Information is tagged with necessary metadata that includes information on syntax, semantics, levels of uncertainty and any other factors that might influence confidence in, or the utility of, the information[65].

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[65] Syntactic heterogeneity refers to a difference in how data and metadata are organized (e.g. rows versus columns in a spread sheet) and encoded (e.g. alphabetic versus numeric information), while semantic heterogeneity refers to the variety in language and terminology used to describe the observations (Horsburgh *et al.*, 2009).

BOX 5.3
Data mining

Data mining is a critical aspect of water accounting and auditing that requires skill and ability in trawling the internet, evaluating, make sense of and blend information that is often of variable quality and stored in a wide-range of different formats.

Source: Horsburgh et al., 2009

5.2.3 Information management: some key issues

Typically the information management component of a water accounting and auditing programme requires resources, skill and patience, not least because the information needed is often fragmented, under the control of different organizations and of variable quality. More positively, advances in cyber-technologies (e.g. remote sensing; unmanned aerial vehicles (UAVs), also called drones; real-time environmental sensors; cloud computing; online global and regional information bases GPS-enabled smart phones) are contributing to:

- Improving the availability of information even for relatively remote areas that are lacking biophysical and societal monitoring networks or programmes.
- Increasing the number of global and regional databases that provide access to biophysical and societal information at no charge.
- Increasing the involvement of 'citizen scientists' in natural resource monitoring[66].

Good starting points for information management include:

- **Field visits to the specified domain:** It is advisable that areas of interest are visited early and people living and working are engaged with in these areas. At the very least, this will provide first-hand appreciation of ground-level realities. This can be extremely helpful when processing and quality-controlling information. Taking and geo-referencing photographs is also advisable as these may provide useful evidence that can be used during discussions.
- **Assessment of earlier or ongoing activities:** Internet searches and brainstorming sessions with stakeholders often reveal that many relevant studies or assessments have already been carried out or are ongoing in or around the specified domain.
- **Rapid assessment of biophysical information:** It is often advisable to spend a few hours or days accessing and reviewing biophysical information that is easily accessible, for example, from sources such as AQUASTAT or Google Earth.
- **Information needs and availability assessment:** Rather than trying to acquire all available information, it is better to carry out a needs assessment that differentiates between information that is 'really needed' and information that 'might be useful'. At the same time, it makes sense to carry out an availability assessment and elicit the views of stakeholders about the quality of information from different sources.
- **Information accessibility assessment:** It is often the case that secondary information exists but for one reason of another is not easy, or even impossible, to access (Box 5.4). If some holders of information are unwilling to share their data, it may be necessary to seek out alternative sources and, in extreme circumstances, select different approaches, methods or models.
- **Need for primary information collection:** Having completed the assessments listed above, the likely conclusion is that primary information will be needed

[66] See http://earthobservatory.nasa.gov/Experiments/CitizenScientist/WaterQuality/

to update, gap-fill or groundtruth the information required, for example, for calibrating and validating a hydrological model. Invariably, this increases the time, costs and other resources that are required. Hence, the general rule in water accounting and auditing is to make maximum use of secondary information.

It is notable that there are ancillary benefits that can be derived from collecting primary information particularly at the local level. For example, primary data collection creates opportunities for: 1) Local stakeholders to participate actively in surveys (e.g. a well survey); and 2) Specialists can spend time in the specified domain interacting formally and informally with stakeholders and developing a first-hand understanding of, for example, land use systems and dominant hydrological processes.

The needs and other assessments described above can be used to develop a strategy for acquiring, processing, blending and quality controlling information. Considerations to be taken into account while implementing this strategy include:

- **Information acceptability:** Various criteria can be used for assessing the acceptability and usefulness of information (see Box 3.5). It is also important to know whether or not information is contested as this may undermine the confidence and trust that some stakeholders will have in the outputs of, for example, spatial analysis or a modelling process.
- **Information storage and sharing:** Information and associated metadata need to be stored and shared in easily accessible forms and formats. It is advisable that a structured information base is used to manage information. Commercially available systems for storing and sharing digitised information are easy to use and an alternative to creating a more complex MIS system. However in all cases, a disciplined structured management of information is needed to ensure that raw, processed, derived and simulated information is not unwittingly mixed together.

  In most cases a balance needs to be struck between storage systems that have a high technical specification (but may be quite difficult to use) and systems that are consistent with the IT skills of potential users. Note that the following may also need to be stored in a retrievable form:

  - Metadata, raw data, processed or derived data, simulated data, field notes and/or model outputs.
  - Photographs, videos, process documentation notes, minutes of meetings, etc.
  - Reference materials and working papers and other documents produced during the water accounting and auditing process.
- **Structured information acquisition and storage:** One option for structuring information acquisition and storage is to use the Resources, Infrastructure, Demand or Access (RIDA) framework (see Section 3.5.3).
- **Blending data from different sources:** In recent years, modelling has made increasing use of information acquired using remote sensing and citizen scientists. In particular, remote sensing, whether from satellites or UAVs, can provide opportunities for parameterising and calibrating models especially in areas with limited or failing hydrometric networks. However, the blending of ground-based, remotely sensed and soft information from citizen scientists is not always straightforward. In some cases, additional processing or modelling is needed to convert remotely sensed information into a form and format that can be entered to a hydrological model (e.g. areal estimates of rainfall and actual evapotranspiration).

BOX 5.4
Accessibility of secondary information

Secondary information may not be accessible or usable for reasons that include:

- Data and Information are not in the public domain. Instead they are held by different organizations and, in some cases, by different departments or individuals within these organizations.
- Data and information relating to water governance and the political economy of water tends to be subjective, long-winded, qualitative and politically biased.
- Owners or custodians will not share data and information because it is politically or commercially sensitive and/or because they want formal or informal payments.
- Data and information are stored in a wide range of formats (e.g. figures, text, maps, remotely-sensed images, photos, tables, graphs) and media types (e.g. hard copies of reports, computer disks or hard drives, local servers, remote servers).
- Data and information are stored in proprietary formats that may only be accessible using commercial software.
- Metadata is unavailable or is difficult to decipher.
- Data points have not been georeferenced or not georeferenced properly.
- Spatial and temporal scales at which the data have been collected are not at all consistent.
- Only aggregate information is available – the disaggregated raw data has been lost.

- **Multiple Independent sources of information:** When acquiring information, it is advisable to obtain information from a range of independent sources. The aim being to triangulate and/or corroborate interesting findings and, in so doing, increase confidence in findings that, in some cases, may be contested.

5.2.4 Information quality assurance and quality control

Typically, the quality of primary or secondary biophysical and societal information is variable (see Box 5.5). Hence, crucial elements of information management are quality assurance and quality control (QA/QC). Ideally, all the information acquired for water accounting and auditing should be quality controlled and everyone involved in collecting and processing information should use the same QA/QC and data handling protocols. These protocols should set out the QA/QC procedures to be followed for different data types and during each step of the information management process. Other important benefits of having properly documented protocols are: 1) They can be used as a basis for training new staff; and 2) They ensure that knowledge is not lost if and when team members move on to other organizations or retire. Box 5.6 lists some typical quality control procedures.

When using water accounting and auditing, it is important to develop a culture that values good-quality data and information with a view to QA/QC becoming the business of everyone involved. Stakeholders, in particular, can play a central part in checking that information is robust and consistent with their own experience of the specified domain.

BOX 5.5

Quality of biophysical and societal data and information is variable

The quality of biophysical and societal data and information is variable for reasons that include:

- Data and information are out of date;
- Methods used to collect data and information that were inappropriate of that do not stand up to scrutiny.
- Poor sampling techniques;
- Poorly trained, poorly motivate and/or poorly supervised field staff;
- Out-dated or false assumptions on who accesses and uses water;
- Use of inappropriate, poorly maintained or incorrectly calibrated monitoring equipment;
- Use of incorrect empirical relationships for deriving useable information from field data (e.g. incorrect rating curves for converting staff gauge data into river flow data);
- Mix ups over units;
- Data that has been collected by organizations that have a vested interest in manipulating or 'cooking' this data (e.g. only reporting information that suggest norms or targets have been met);
- Either no information manager or an information manager who is insufficiently trained or motivated to process and quality control data and information effectively;
- Incorrect or missing metadata;
- Protocols not followed when collecting, for example, water samples and subjecting them to chemical analysis.

5.2.5 Information management: new horizons

New information management technologies and cyberinfrastructure[67] are emerging that could transform many aspects of water accounting and auditing. While this is exciting, some caution is advised. For example, large amounts of money have been invested globally to manage information systems[68] that have been designed and created to improve the availability of information and sharing but, for one reason or another, they have failed to live up to expectations[69]. Clearly both positive and negative lessons need to be learned from these experiences. There is also the risk that high-tech solutions will: 1) Lead to overconfidence in the information provided (Beven, 2012); or

[67] The generic term cyberinfrastructure is used to describe the infrastructure that takes advantage of recent advances in information technology.

[68] A management information system (MIS) provides information that organizations need for their efficient and effective management.. Management information systems are typically computer systems used for managing three primary components: technology, people (individuals, groups, or organizations), and data (information for decision-making). Management information systems are distinct from other information systems, in that they are used to analyse and facilitate strategic and operational activities.

[69] In some cases, MIS systems have failed because they were implemented as a technical quick fix to complex institutional and political problems such as sharing of information.

BOX 5.6
Quality control procedures

Quality control methods include:

- Computer based techniques for checking for errors in numerical data (e.g. filtering, range checks, cross-correlations, 'eyeballing' scatter diagrams).
- Triangulation by comparing different independent sources (ideally three or more to establish accuracy and reliability of data and information).
- Benchmarking which involves structured comparison with information from other settings.
- Ground-truthing secondary information by making field visits, semi-structured dialogue with stakeholders at different institutional levels and/or collecting new data from a representative sample.
- Establishment of expert panels – particular useful with qualitative societal information.
- Constructive use of social media, online forums, online workshops or questionnaires.
- Social audits and forensic accounting.
- Crowdsourcing that involves putting data and information on an open-access web-site (possibly in a wiki format) and asking the public or citizen scientists to verify, critique and/or amend data and information.
- Only use data and information from trusted sources.
- Giving more credence to empirical data and information and being wary of mixing empirical and simulated data and information.

2) Inadvertently alienate key stakeholders who may feel more comfortable using more traditional approaches to information management.

BOX 5.7
Using remote sensing to monitor ET

Techniques for estimating ET on large areas over time using satellite remote sensing were developed in the late 1970s. The most extensively validated techniques estimate ET by solving the energy balance of the surface using thermal and visible bands. In addition, other approaches exist that, for example, relate ET to vegetation indexes. As of today, there is no globally validated ET product available, and several international agencies, including FAO, and research institutions have joined forces to develop operational methodologies and databases.

Some emerging information technologies and cyberinfrastructure that are already being used in water accounting and auditing type programmes include:

Information acquisition

- Remote sensing of water balance components: Thermal infrared-based ET monitoring has reached a stage where it is operationally and economically feasible obtain ET information at accuracies and spatio-temporal resolutions that are required for many practical water resource applications (Anderson et al., 2012)(see Box 5.7). A similar stage has been reached with estimation of: remotely sensed rainfall[70] and remotely sensed soil moisture and groundwater conditions[71].

[70] e.g. http://trmm.gsfc.nasa.gov/

[71] e.g. http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx

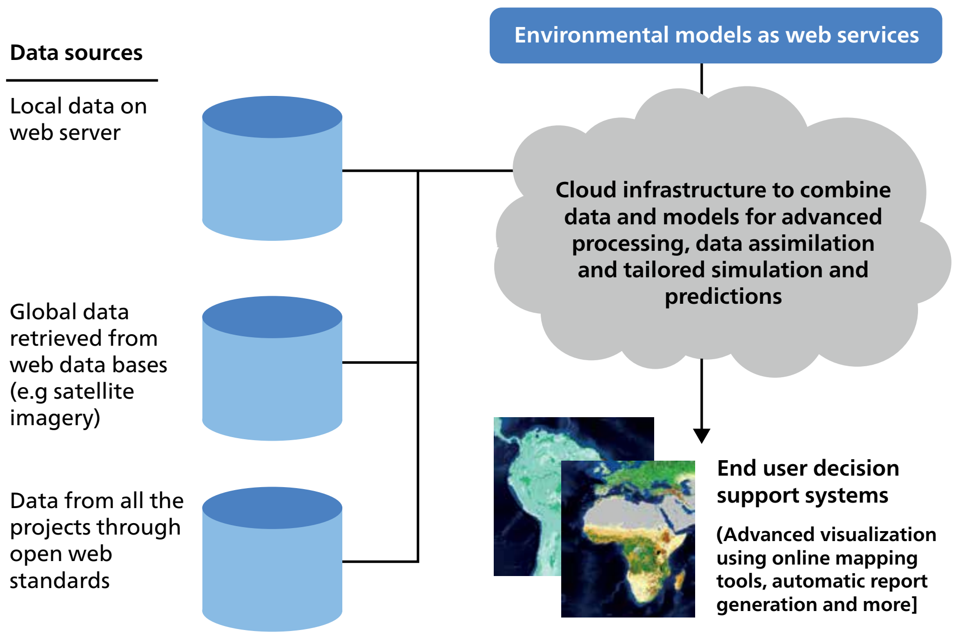
- **Unmanned aerial vehicles (UAVs)** or drones offer the opportunity for individual scientists or small teams to obtain low-cost repeat imagery at high resolutions (1 cm to 1 m) tailored to specific areas, products and delivery times of interest to research (Vivoni *et al.*, 2014).
- **Terrestrial environmental sensors** are being developed that are relatively-cheap and that can wirelessly stream data over local networks and the internet (Buytaert *et al.*, 2012).
- **GPS-enabled smartphones** are having a major impact on users' abilibity to report problems or inadequacies in the services they receive using applications such as AKVO Flow[72] or Water Point Mapper[73]. GPS-enabled smartphones can also improve the potentially valuable contribution that citizen science networks can make to water accounting and auditing by, for example, monitoring and reporting biodiversity indicators.

Accessing and sharing information

- **Virtual observatories** can link and integrate: 1) Global, national and global information bases (containing both terrestrial and remotely sensed biophysical and societal information); 2) Networks of environmental sensors; 3) Information collected by users of water services or by citizen scientists; and, 4) Interconnnected web or cloud-based services or application (see Figure 5.1) (Laniak *et al.*, 2013).
- **IT applications** that have built-in capabilities for locating and accessing water-related information from the internet. An example of this approach is the CUAHSI Hydro-Desktop[74] application that provides access to remote data

FIGURE 5.1

Schematic of a virtual observatory of interconnected web services providing interactive information products and/or simulations



Source: Buytaert et al., 2012

[72] For more information see: http://www.akvo.org/web/introducing-akvo-flow

[73] For more information see: http://www.waterpointmapper.org/

[74] For more information see: Ames *et al.* (2012) and/or http://hydrodesktop.codeplex.com/

archives using the CUAHSI WaterOneFlow web service (Ames *et al*., 2012; Tarboton *et al*., 2009, Laniak *et al*., 2013). In HydroDesktop, the functionality for both searching and downloading data is executed on remote servers with their own databases.

Information communication

- **Interactive visualisations** enable users to access and explore information that is of particular interest to them. As a result, users have a level of control that is not possible with static infographics or sequential videos[75].

5.3 INTEGRATED ANALYSIS AND MODELLING

5.3.1 Overall approach

The overall aim of integrated analysis and modelling is to build on earlier outputs and findings by developing and testing strategies with the potential to achieve, if not all, a number of objectives articulated in a shared vision. Up to this point, the aim was to address individual problems, concerns or issues. Modelling is central to the approach recommended here as is scenario building that integrates, quantitative and qualitative information, analysis and understanding from the earlier phases of water accounting and auditing. However, before proceeding with this phase, a judgement should be made on whether or not adequate information and understanding have been acquired to justify and warrant using integrated analysis, modelling and scenario building. If there are still significant gaps in the biophysical and societal information or understanding of the specified domains, it is advisable not to start this phase until these gaps have been filled.

Typical activities during this phase include:

- Combining, integrating and interpreting the findings and outputs from earlier parallel water accounting and auditing activities, assessments and analysis.
- Using integrated analysis and modelling to look in more detail at underlying biophysical and societal causes of water-related concerns and issues in the specified domains and the potential utility of opportunities for addressing these causes.
- Using integrated analysis, modelling and scenario building to assess the probability that strategies (i.e. combinations of opportunities) will achieve a shared future vision across a range of plausible scenarios.
- Assessing whether these strategies have potential externalities within or outside the politically or socially unacceptable specified domains.

5.3.2 Modelling overview

Modelling has a number of functions in water accounting and auditing that include:

1. Improving and/or reality checking our understanding of the dominant biophysical and societal processes that are for example influencing current trends in water supply and demand in the specified domains.
2. Predicting and/or estimating water balance components at the scales of interest even when access to empirical information is limited.

[75] http://www.visualisingdata.com/

3. Predicting or forecasting the potential impacts of changes in, for example, land and water management, on patterns of access to water.
4. Assessing the economic trade-offs in space and time of water allocation to agriculture, hydropower, and municipal and industrial sectors and/or of maintaining environmental flows.
5. Supporting and improving the rigour of scenario analysis and strategy development.

BOX 5.8

A healthy scepticism is needed when using models

Models should always be applied carefully and their results interpreted critically. To quote Woolhiser and Brakensiek (1982):

> *"All theoretical models simplify the physical system and are, therefore, more or less incorrect. In addition, the so-called theoretical models often include obviously empirical components. All empirical relationships have some chance of being fortuitous; that is, by chance two variables may appear to be correlated when in fact they are not."*

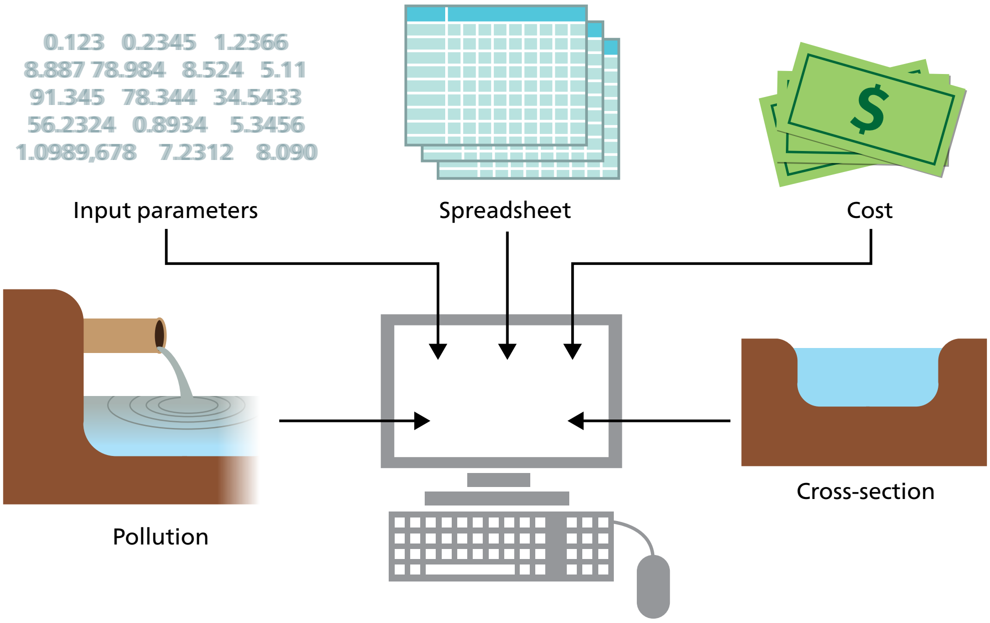
For all but the first function listed above, the model(s) must provide a good representation of relevant biophysical and societal processes or systems within acceptable levels of uncertainty. This is not as important for the first function. Additional functions of modelling include: supporting decision-making, social and institutional learning, flood forecasting and assessment of value for money.

Reasons for using hydrological, hydro-economic and integrated approaches to modelling include:

- Providing analytical evidence to support decision-making for policy development or multi-scalar planning.
- Supporting interdisciplinary lesson learning by systematically combining scientific and local knowledge or through cycles of institutional and social learning.
- Integrating information and knowledge across disciplines, across sectors, across spatial and temporal scales, along value chains or similar.
- Testing different 'what if' or 'what is best' hypotheses across a range of conditions or scenarios.
- Identifying and assessing the scale and severity of externalities or trade-offs that may result from implementation of different policies or decisions.
- Assessing the resilience of land and water management strategies such as to climate change.
- Exploring the frequency and potential impacts of extreme biophysical events (e.g. floods or droughts) or societal shocks (e.g. major changes or fluctuations in the cost of energy).
- Exploring probabilistically the relative importance of social and political economy factors that influence, for example, the adoption (or otherwise) of improved land and water management practices.
- Investigating the marginal costs and benefits of different activities, strategies or similar.

Models can be sophisticated and provide detailed representations of biophysical and societal processes. Models can also be relatively simple, such as an empirical relationship that estimates the amount of runoff based on precipitation and parameterisation of

FIGURE 5.2
Model overview



some important catchment characteristics. This sourcebook focuses on three main categories of models: hydrological, hydro-economic, and integrated models other than hydro-economic models. Before considering each of these categories in more detail, it is important to recognize that any given water accounting and auditing process may need to use a range of additional models related to, for example, the hydraulics of water-supply systems, soil erosion, agricultural production and aquatic ecosystems.

In water accounting and auditing, the potential value of engaging with stakeholders, especially in the problem-framing stage of a modelling process, cannot be over-emphasised (After Jakeman *et al.*, 2013). While participatory approaches to modelling can be time and energy consuming (for all involved), they provide stakeholders with an opportunity to influence the modelling process. Participatory approaches also help build ownership, trust and confidence in the modelling process and outputs. However, a particular challenge that may need to be managed sensitively is any major divergence between existing scientific evidence and the perceptions or belief systems of stakeholders. A well-planned communication strategy is needed to handle such an eventuality.

Modellers often connect, couple or link models together to describe an entire process or system (Shoemaker *et al.*, 2005). The use of multiple models is necessary when multiple features of the system cannot be sufficiently described by one model (e.g. it is common practice for separate ground and surface water models to be linked). These linkages between models can be static or dynamic. A static linkage takes output from one model and uses it as input to a second model. A dynamic linkage can be bi-directional, where information from each time step transfers back and forth between the models and affects the simulations or optimisations of one or both of the models. Modellers often implement linkages through a simple file transfer system or a common database. Some models or modelling software systems provide software-enabled linkages so that all file exchange requirements are automatically performed as the models are applied[76].

[76] e.g. OpenMI is a standard interface definition that allows compliant models to exchange data as they run. http://www.openmi.org/new-to-openmi

5.3.3 Hydrological models

Hydrological models can be grouped into two model types: *deterministic* and *stochastic*[77]. A *deterministic model* produces one set of outputs from one set of parameter values, input variables[78] and boundary conditions[79]. Whereas a stochastic model produces a range of outputs from one set of parameter values, input variables and boundary conditions. Deterministic models are based on the assumption that hydrological events are governed by a fundamental set of hydrological processes that are subject to a unique set of initial and boundary conditions. Stochastic models, on the other hand, take account of the unpredictability of nature by representing hydrological events as probability distributions.

Hydrological models can also be grouped according to *whether* they are *lumped* or *distributed*. Lumped models treat a catchment as a single unit with variables that represent averages over the whole catchment or discrete units within the catchment. Distributed models make predictions that are distributed in space by discretizing a catchment into a large number of grid squares and solving equations for variables associated with each grid square.

Table 5.1 lists and describes the characteristics of some typical hydrological models. The models in this table have been ordered intentionally to reflect increasing data requirements. In general, empirical models have the least demanding input requirements while distributed models are likely to be the most demanding.

5.3.4 Hydro-economic models

Hydro-economic models (HEMs) can be used to integrate and analyse the complex hydrologic and economic interrelationships that are inherent in water resources and water services delivery systems (Bekchanov, 2015). HEMs can also be used to assess the utility and impacts (positive and effect) of, for example, policy and infrastructural responses to increased water scarcity. More specifically, HEMs help water managers move from a relatively static view of water demand of different water users and uses to a more dynamic view of demand as related to strategies that aim to maximize the net benefits of water allocation in space and time (Harou *et al*., 2009). A central concept being that water demands are not fixed requirements but rather functions where quantities of water use at different times have varying total and marginal economic values.[80] Water is more valuable during a drought than, say, a rainy season, and water supply costs tend to increase disproportionally when all local water sources are fully exploited or allocated. Despite this fact, management and allocation of water is often based on the assumption that the economic value of water supply or service delivery

[77] It is notable that some hydrological modelling systems incorporate both deterministic and stochastic elements or options.

[78] In order to generate outputs, models use parameters and variables. In this sourcebook, we define a parameter as a quantity that represents the intrinsic characteristics of the system being modelled and, as such, a parameter usually appears as a coefficient in equations or algorithms used by the model, In contrast, a variable can be both entered into and calculated by the model. As the name suggests, a variable is a quantity that represents a process or a feature that is liable to change in time and space.

[79] It is often necessary to define boundary conditions so that a location-specific hydrological model can interact with entire hydrological flow system. Boundary conditions are often defined, described or assumed to be constant or invariant.

[80] For more information on water demand curves see FAO (2012).

TABLE 5.1
Characteristics of some typical hydrological models

Type	Description	Benefits	Drawbacks
Empirical	Outputs are inferred from statistical relationships derived between outputs and selected inputs.	Simple, but can provide good results depending on the effectiveness of model calibration and validation.	Catchment and climate dependent. Calibration can require several decades of data.
Water balance	Simple parameterisations leading to estimation of average annual or monthly water balance components (usually stream flow or groundwater recharge).	Another simple approach. Takes account of the Law of Conservation of Mass and the inter-connectedness of hydrological processes	Requires calibration for individual catchment and climatic characteristics. Uncertainties will be large if used in catchments that have a complicated mosaic of, for example, land uses.
Lumped	Physical processes are represented directly by sets of equations. Such a representation can only be approximate and often involves some degree of empiricism. Processes are usually represented at the catchment scale.	Improved estimates provided by more detailed process simulation and higher temporal resolution. Potentially spatially transferable.	Increasing parameter and data requirements. Poor spatial resolution. Hydrological response units that lump together different land uses are not geo-referenced.
Semi-distributed	Similar to lumped models in that a physical approach is taken but spatial resolution is accounted for by using probability distributions of at least some input parameters across the catchment	All the advantages of lumped models but improved results might be expected due to the implicit representation of sub-model scale variability.	Potential difficulties in deriving input parameter distributions and in interpreting the results in practical situations. Not spatially specific.
Distributed	Similar to lumped models in that a physical approach is taken but with improved spatial resolution gained by dividing catchment into component areas.	Physical process representation with good spatial and temporal resolution. Spatially specific in the extent that subcatchment responses can be investigated.	Generally requires large amounts of (often unavailable) data for parameterization in each component area. Computationally intensive for large catchments at high resolutions
Hybrid	Hybrid models or modelling systems combine and use a number of the approaches listed above; often by allowing users to select the modelling approach	Allows users to select modelling approach that matches their needs and/or the data that are available	Assumptions inherent to each approach may be inconsistent.

are fixed and independent of, for example, the life-cycle costs of the delivery of water services[81].

HEMs can be classified broadly into two categories on the basis of their structure. The first category are node-based river basin management models that include both simulation and optimization models[82]. The second are economy-wide models that

81 Life-cycle costs refer to the aggregate costs of ensuring delivery of adequate, equitable and sustainable water services to a set of water users or uses in a specified area. Also referred to as ‘cradle to grave’ costs.

82 Although simulation and optimization models are often considered as being different categories of model types, much of the underlying structure of such models can be considered to be similar (Bekchanov, 2015).

include Input-Output models (IOM)[83] and Computable General Equilibrium (CGE)[84] models. In contrast to node-based models, economy-wide models consider simplified water use relationships by including water as one factor of production in addition to capital and labour resources. River basins or subcatchments are considered as single-nodes that can supply water to any economic sector that utilize it. Such models typically emphasize economic relationships, intermediate uses, and sectoral inter-linkages and usually devote less attention to the spatial and temporal dynamics of water systems (Bekchanov, 2015).

BOX 5.9

Uses or applications of hydro-economic models

Uses and applications of hydro-economic models include:

- Evaluation of water management scenarios or strategies;
- Infrastructure expansion and operations planning;
- Water allocation and markets;
- Impact analysis and adaptation pathways (e.g. to climate change);
- Design of institutional policies to achieve environmental, social and economic targets;
- Economic policy impact analysis;
- Basis for regulation and legislation.

Source: Harou et al. 2009

When comparing IOM and CGE models, IOMs tend to be more descriptive tools that explain static conditions, while CGE models tend to be more useful for simulating and predicting the effects of economic perturbations or input/resource-based shocks. As a result, IOMs usually include relationships between water uses, economic outputs, and final consumption. CGE models additionally consider price-commodity demand relationships, production functions and income generation/ distribution relationships.

The main components of HEMs are mathematical representations of the hydrologic relationships in the water system and the water demand and production relationships of different water-using sectors (e.g. agriculture, industry, rural and urban water supply and hydropower production). Early applications used a relatively simple model structure to examine a limited set of sectors and water allocation problems (e.g. Ward and Lynch, 1996). As modelling techniques have progressed, however, increasingly complex and sophisticated processes, such as detailed agronomic and groundwater relationships, and various representations of environmental flow requirements (benefits) are now routinely included in such models (Bekchanov, 2015).

Currently, a majority of economy-wide models have been developed at the national level, which neglect the economic and physical differences across regions within a country. In contrast to node-based models, economy-wide models usually assume a single node for the entire basin or sub-basin that provides water for all economic sectors. IOMs have been used for very limited types of analyses. In contrast, CGE models are more powerful tools that have been used to assess a broader set of policy questions. In fact, these models have been widely used for analysing the impact of water supply reduction, changes in water pricing, and infrastructure improvements on

[83] In economics, an input–output model is a quantitative economic technique that represents the interdependencies between different branches of a national economy or different regional economies.

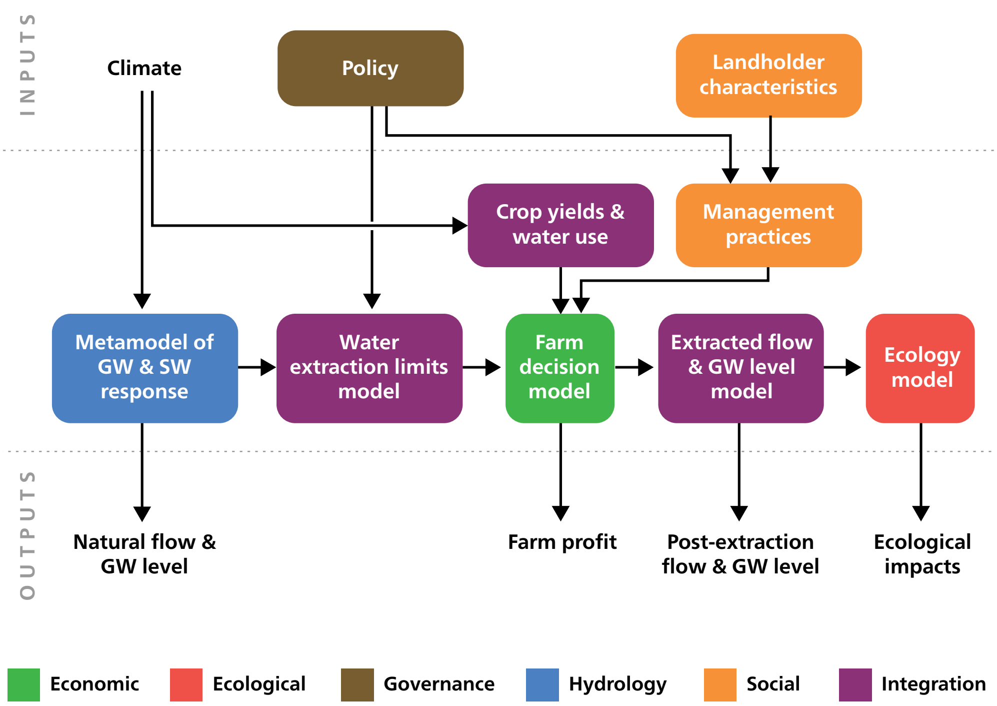
[84] Computable general equilibrium (CGE) models are a class of economic model that uses actual economic data to estimate how an economy might react to changes in policy, technology or other external factors

sectoral water uses, economic output, income distribution, final consumption, prices, and foreign trade (Bekchanov, 2015).

An important challenge in using HEMs, and especially economy-wide models such as IOMs and CGEs, is their limited spatial and temporal resolution. Hydrological systems respond on a variety of scales: many important processes (environmental and peak flow dynamics that are relevant for ecosystem service production, floods or droughts) play out at very short time scales of minutes to hours, while others occur on a daily to weekly time frame (e.g. water delivery to irrigated agriculture), or on much longer monthly, annual, or even decadal scales (e.g. reservoir storage, seasonal or inter-annual variability in river flows, and climate change) (Islam and Susskind, 2012). Similarly, physical processes such as river flow and groundwater recharge do not fit cleanly with the political boundaries that correspond to many national or regional water management institutions.

In recent years, there has been increasing recognition that planning and management decisions rarely only rely on the hydrological, hydraulic and economic aspects of a water supply or services delivery system. Social priorities such as risk aversion are not readily represented in either hydro-economic model objectives or constraints. Hydro-economic model objective functions typically seek to maximise expected net benefits (or minimise expected costs) whereas benefits and costs are strictly weighted by their occurrence probability. However, this risk neutral expression undervalues the desire of decision-makers to avoid the severe consequences of extreme, albeit unlikely, events. As a result, some innovative hydro-economic models now take into account some social and political economy aspects of water governance and water delivery systems (e.g. Blanco-Gutiérrez *et al.*, 2013).

FIGURE 5.3
Example of an integrated model schematic developed for the Namoi catchmet

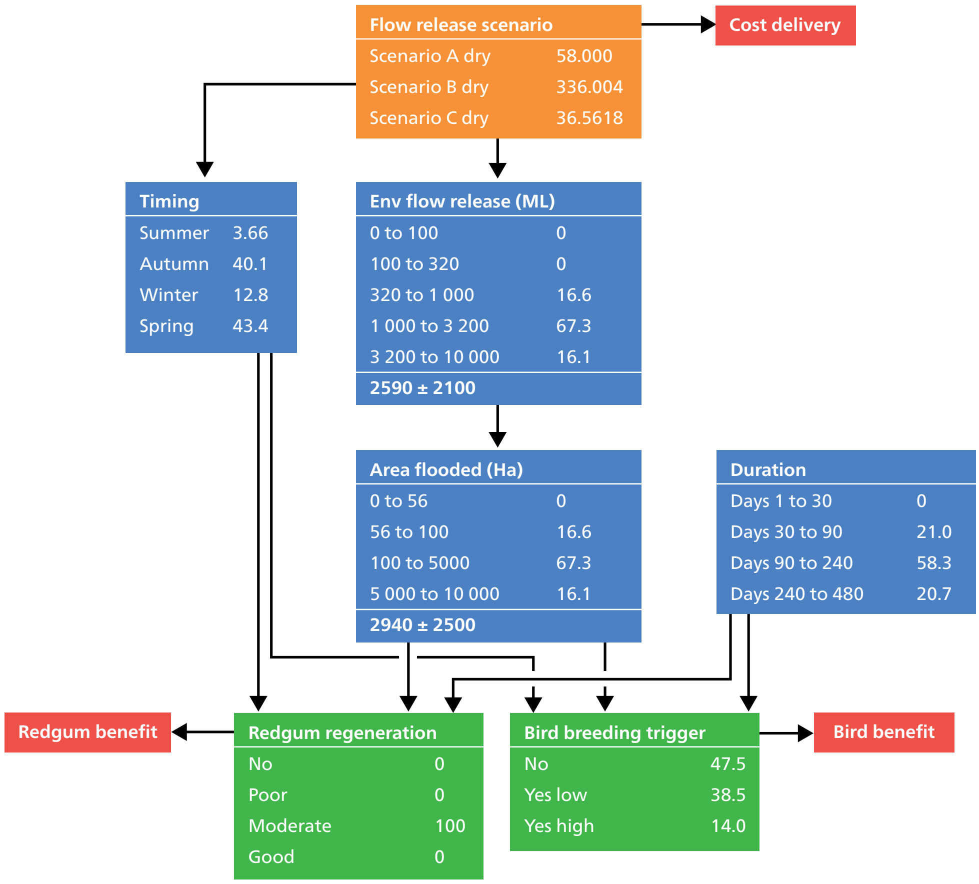


Source: Croke et al., 2012

5.3.5 Other integrated models and modelling systems

Various methods have been used to add value and to improve integrated approaches to modelling. These include Bayesian networks[85] and agent-based modelling[86]. Bayesian networks, also known as Belief networks, provide a methodology for representing and analysing probabilistic relationships between variables. The methodology is particularly relevant to the investigation of biophysical systems and societal impacts on these systems because it works well even if relationships and interactions involve uncertainty, unpredictability or imprecision. In addition, participatory development of Bayesian networks enables stakeholders to reach a common understanding of the nature and causal linkages between biophysical and societal factors central to the success of, for example, watershed management interventions. This is aided by the fact that Bayesian networks are flexible and capable of: 1) Capturing knowledge in a way that is easy to understand by non-specialists; and 2) Informing decision-making based on variables that are difficult to quantify. However, despite advantages of Bayesian networks, they also have some limitations e.g. they cannot easily handle feedback mechanisms.

FIGURE 5.4
Example of a Bayesian network developed to investigate the environmental benefits of flow release scenarios



Source: Pollino and Henderson, 2010

[85] For more information on Bayesian networks see this online tutorial: http://www.norsys.com/tutorials/netica/secA/tut_A1.htm and the guide prepared by Pollino and Henderson (2010).

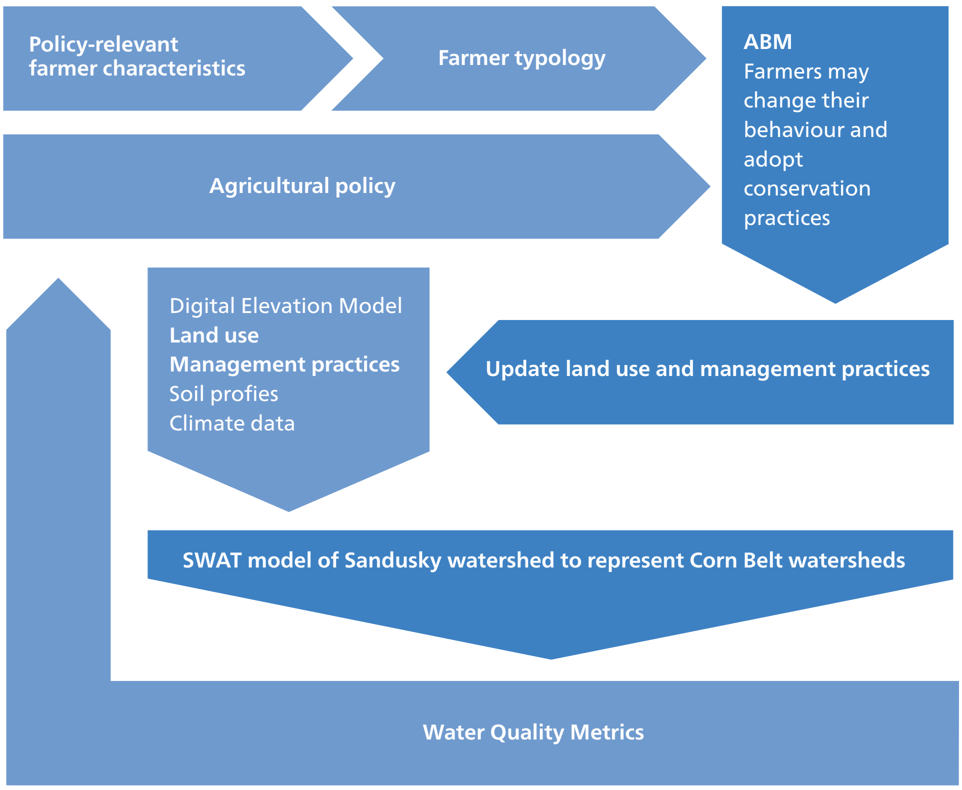
[86] For more information on agent-based modelling see this online tutorial: http://www2.econ.iastate.edu/tesfatsi/abmread.htm and the guide prepared by Macal and North (2006).

Agent-based modelling (see Figure 5.5) is used to simulate the actions and interactions of agents (both individuals and collective entities such as organizations or groups with a view to assessing their effects on the system as a whole). More specifically, it is a method for studying systems exhibiting the following two properties: (1) The system is composed of interacting agents; and (2) The system exhibits emergent properties that arise from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents. Figure 5.5 is a schematic of an agent-based model that represents the adoption of conservation practices by farmers built around a water quality model and the Soil and Water Assessment Tool (SWAT). This was used to simulate the water quality effects of changing land tenure dynamics and different policies for crop revenue insurance in lieu of commodity payments over 41 years (1970–2010) for a predominantly agricultural watershed in Michigan State, the United States (Daglogu *et al.*, 2014).

5.4 HYDROLOGICAL MODELLING STEPWISE PROCESS

This section describes a typical stepwise modelling process that can be used with hydrological models as part of water accounting and auditing (see Figure 5.6). Although modelling is presented as a linear process, it is often necessary to repeat some steps and, depending on the context, it is not always necessary to take all the steps in this order. Note that a similar process can be used when selecting, setting up, calibrating, validating and using other types of models.

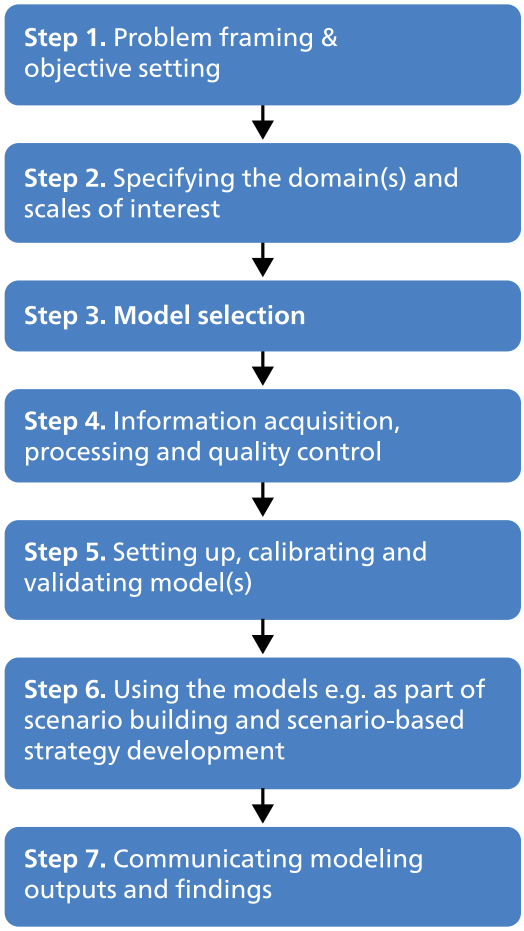
FIGURE 5.5
Example of an agent-based model that was developed to support farmers' decision-making in Michigan State, USA



Source: Daglogu et al., 2014

Step 1: Problem framing and objective setting. Typically this step starts with stakeholder dialogue that prioritises issues and concerns to be addressed in the modelling. Facilitation may be needed if there are differences in the ways in which key stakeholders frame, or perceive, issues and concerns.

FIGURE 5.6
Typical modelling steps



Problem framing is followed by identification of the main objectives of modelling, the questions to be addressed and the outputs required. At the same time, consideration should be given to how the modelling outputs will complement and/ or support: integrated analysis; scenario building and analysis and scenario based strategy development and testing.

Note that outputs from the earlier targeted biophysical assessments in the specified domains and, possibly, water balance and fractional analysis should be used to inform discussions during this step. Similarly, the perceptual model(s) that were developed and refined during the earlier phases of water accounting should be useful.

Step 2: Specifying the modelling domains and scales of interest is a crucial step because it determines the issues and questions the model will, or will not, be able to address. This step often involves a certain amount of trial and error. One common reason is that the availability of data often dictates the scales at which effective calibration and validation is possible. This information may be readily available at one scale, or geographical location, but not another. Another option is to use a combination of upscaling, downscaling and regionalization, but there is a risk that this will introduce unacceptable levels of uncertainty (see Box 5.10).

More positively, modern modelling systems include GIS applications that can be used to test out different spatial scales and user interfaces that make it relatively easy to evaluate different temporal scales. In addition, guidance on regionalizing hydrological variables is available online[87].

Step 3: Hydrological model selection. In most cases, the model(s) to be used are selected from existing models or modelling systems that are well proven and well documented. Selection will be based on the: 1) Objectives agreed during Step 1; 2) Biophysical perceptual model of the specified domain; and 3) On the information that is or is likely to be available for calibrating and validating the models. However, other criteria should also be considered. These include (see Box 5.11):

[87] For more information and guidance on regionalising hydrological variables see: http://www.unesco.org/new/en/natural-sciences/environment/water/ihp/ihp-programmes/friend/ and Hrachowitz *et al.* (2013)

BOX 5.10
Scaling and regionalisation

The scales at which hydrological modelling is applied tend to be influenced by: 1) The scales used historically in most research studies; 2) The scales used by model developers (this has been influenced by scales used in research studies); and 3) Typical applications of hydrological models.

In space, typical modelling scales are: the local scale (1 m); the hill slope (reach) scale (100 m); the catchment scale (10 km); and the regional scale (1 000 km).

In time, typical modelling scales are: the event scale (1 day); the annual or seasonal scale (1 year); and the long-term scale (100 years).

Unfortunately, more often than not, the modelling scale is much larger or much smaller than the observation scale (i.e. the scales at which empirical data are available) and/or the scales at which decisions are made by, for example, democratic institutions and water users. To bridge these gaps in the absence of additional empirical information for calibrating and validating model, 'scaling' is needed. However scaling adds to the uncertainty in model outputs.

> *"In a hydrological context, upscaling refers to transferring information from a given scale to a larger scale, whereas downscaling refers to transferring information to a smaller scale. For example, measuring hydraulic conductivity in a borehole and assuming it applies to the surrounding area involves upscaling. Also, estimating a 100-year flood from a 10-year record involves upscaling. Conversely, using runoff coefficients derived from a large catchment for culvert design on a small catchment involves downscaling. Regionalization, on the other hand, involves the transfer of information from one catchment (location) to another. This may be satisfactory if the catchments are similar (in some sense), but error-prone if they are not (Pilgrim, 1983). One of the factors that make scaling and regionalization so difficult is the heterogeneity of catchments and the variability of hydrological processes".*

Source: Bloschl and Sivapala 1995

- **Relevance:** Even if the model has been reviewed in the literature and has been applied with some success in the region in which you are working, it is advisable to make sure that it is relevant to: 1) Your perceptual model of the dominant biophysical processes in the specified domain; 2) Some or all of the specific needs of your modelling study; and 3) The questions agreed during Step 1.
- **Utility:** Clearly the model(s) selected should have the level of functionality required and be able to produce outputs that have acceptable levels of uncertainty. It is also important to consider whether the model is able to deliver desired outputs with an acceptable level of uncertainty given prevailing constraints (e.g. availability of data).
- **Credibility:** In general, it is best to use models recommended by well-respected academics or that are often mentioned in peer-reviewed journals or project reports. Use of modelling is now so widespread, it is possible that stakeholders will have strong opinions as to the credibility of models, particularly if they have been involved personally in a modelling process that failed to meet expectations.

BOX 5.11

Typical criteria to use and questions to ask when selecting a model

Relevance

- Is the model relevant to some or all of the issues and concerns in the specified domain?
- Is the model relevant to the specific biophysical and societal context of the specified domain(s)?
- Can the model play a role in answering some or all questions that are being asked?

Utility

- Does the model have the functionality required to serve the intended purpose?
- Will the model produce acceptable outputs given with data that are available?
- Is the model likely to deliver the level of accuracy needed?

Credibility

- Does the model have academic credibility e.g. has it been reviewed positively in peer-reviewed literature?
- Do stakeholders trust the model?
- Has the model already been used successfully or been applied in the specified domain(s) and/or a similar contexts elsewhere?

Usability

- How easy is the model to use in this context?
- Does sufficient capacity already exist to use the model?
- Is support readily available online e.g. in the form of tutorials or chat rooms?

Source: EPA, 2008.

Usability may not be an important criterion if the model(s) are to be used for research purposes. However, it may be critically important for many practical applications. The risk here is that off-the-shelf modelling software will be selected because of its usability regardless of credibility, utility and relevance.

Personal biases can and often do play a role in model selection. For example, some stakeholders or specialists may wish to select a model only because they have had some training in its use, and not because it is the best model available for a particular task or context. Cost also influences selection of models and/or modelling software and, as a result, there is an increasing tendency for non-academic model users to select open-source versions off-the-shelf modelling software.

Step 4: Data acquisition, processing and quality control: If the water accounting and auditing process has been followed, much information already will have been collected, quality-controlled, analysed and stored along with relevant metadata. However, the selected model may require acquisition of additional information. If this is the case, a decision will have to be made on whether to acquire more information or to select another model.

BOX 5.12
Some modelling terminology

- **Calibration** is an iterative process of fine-tuning the model to a set of field data, preferably data that were not used in the model construction.
- **Verification** is the statistical comparison of the model output to additional data collected under different forcing and boundary conditions.
- **Validation** is achieved through calibration and verification so that the model is an accurate representation of the real system or catchment being modelled

Source: Sharpley et al., 2010

Step 5: Calibration, validation (and verification), sensitivity tests and managing uncertainty: Calibration is the process of selecting and tuning the parameters in the model so that it performs well when validated against empirical data. The way in which calibration and validation is used is dependent on the type of model that has been selected. For empirical and water balance models, parameter adjustment will generally be guided by the fit between the model output and the observed behaviour as judged by calibration tests. For physically based models, however, parameters are chosen to represent physical realities and, as a result, parameter values are expected to be within realistic limits. Such constraints can often be problematic; especially when only limited information is available on the range of values a parameter might take in the biophysical context under consideration. Models should always be tested (i.e. calibrated and validated) before they are used in any application. Typically, the testing process involves graphical comparisons of observed and simulated information and statistical tests (see Box 5.14). Most modellers start by comparing time series or scatterplots of observed and simulated data relating to, for example, river discharges or other water balance components. The objective being to improve the model and identify features that may have been missed during setup.

In the later part of model testing, the emphasis is on producing proof that the model is working well and providing results that stand up to scrutiny. In cases where additional data gathering is not possible and historical records are limited, testing might be based on a single downstream location. In all cases, it is important to delineate the domains being modelled so that opportunities can be maximised for comparing observed and simulated variables. Sometimes, when data are highly limited, model testing is based primarily on regionalisation or scaling of hydrological parameters and variables. However, choices and assumptions made regarding the approach to calibration and validation will influence levels of uncertainty, or confidence, in model outputs (see Box 5.16).

BOX 5.13
What's the difference between model validation and calibration?

Calibration and validation are two separate procedures in model development and testing. Typically, available monitoring data are separated into two different time periods for testing. Using one dataset, calibration parameters are adjusted, within reasonable ranges, until a best fit to observed data is generated. Using the second dataset, validation is performed by keeping the parameter set constant and testing the performance of the model. Time periods for calibration and validation are carefully selected to include a range of hydrologic conditions.

Source: EPA, 2008

Additional model calibration and validation challenges and considerations include:

- **Simple empirical models** are intended for use only in the conditions for which they are calibrated. However, accessing sufficient historical data with which to derive a satisfactory correlation may be a challenge. There may also be a problem of non-stationarity in this relationship over the calibration period because of, for example, land use change or increased water storages and diversions in the specified domain.
- **More complicated** models may suffer from parameter inter-correlations that can mask model and data uncertainties. Under estimation in one parameter may be compensated for by over estimation in another, resulting in the right answer for the wrong reason. However, this may be more acceptable in simple models where the right answer may be more important than the right reason, but such an eventuality undermines the entire conceptual basis of physical models.
- **Heterogeneity** also presents a problem for model validation. With the notable exception of discharge data, most other ground-based measurements represent a physical property at a single point in space and time (e.g. rainfall measured by a rain gauge). In general, models aim to produce outputs that represent the combined results of processes. These processes are controlled by physical properties that vary across the area, or time frame, being considered. It then makes little sense to compare this output to measurements that arise from processes that are controlled by a single set of physical properties at a single point. A possible solution to this problem is to make use of remote sensing that estimates values aggregated over large areas. These approaches, however, also come with their own uncertainties and scaling issues.
- **Iterative and adaptive approach to model calibration and testing:** There is often merit in taking an iterative adaptive approach to calibrating and testing models. The aim being to refine and re-test the model as more information becomes available. If this process goes well, each cycle will reduce the uncertainty, and increase the confidence, in the model and subsequent model outputs or applications. However, models cannot be expected to be more accurate than the prediction limits of the model[88].

BOX 5.14

Example calibration tests

Regression: Model output is plotted against observed data, and a regression equation can identify the relationship between modelled and observed values and the goodness of fit.

Relative error: Modelled errors are measured by comparing simulated flow values with observed flow values for various periods (e.g. for the summer) using the following equation:(Simulated value – observed value)/observed value A small relative error indicates a better goodness of fit for calibration.

Model coefficient of efficiency: This value measures the ratio of the mean square error in model predictions to the variance in the observed data. Values range from minus infinity to 1.0; higher values indicate better agreement.

Nash-Sutcliffe efficiency (NSE): The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance (‘noise’) compared to the measured data variance (‘information’).

Source: EPA, 2008.

88 Beven and Binley (2014) discusses the reasons for there being an upper limit of performance for a set of models (even models with many fitting parameters) and for observed performance during ‘validation’ periods often being poorer during calibration periods (see Figure 5.7).

BOX 5.15
Documenting a modelling process

- When setting up, calibrating and validating a model it is important to document the modelling process. As a minimum, the model documentation should include:
- model name and version;
- purpose of model application;
- model assumptions particularly those that could limit the usability or utility of model outputs or applications;
- data requirements and sources of input data.

Source: EPA, 2008.

- **Assumptions:** Calibrating and validating models is not an exact science. Judgements and assumptions have to be made. As these are easily forgotten, they should be documented (see Box 5.15). Assumptions should also be reported and made explicit when communicating findings.
- **Peer review:** Towards the end of a calibration and validation process, it is often advisable to ask another modeller to review and provide feedback on, for example, the modelling objectives, the model set up, the results of the calibration tests and the assumptions.
- **Local knowledge:** It is possible to use citizen scientists, farmers and local professionals as sources of information to use for calibrating models. However, as this can be a source of bias, caution is needed and much attention needs to be given to the collection and use of this information. Rather, stating the obvious, people have good recollections of extreme events (e.g. when floods occurred, the extent of flooding, failures of water supply systems, etc.) but they are a less reliable source of information relating to small incremental changes.
- **Return flows:** Empirical information on return flows (e.g. from an irrigation scheme or an urban area) is rarely available. Hence return flows are often taken as the residual in water balance analysis and, as a result, uncertainties are high. If the water accounting programme has a particular interest in return flows, it may be worth the effort to model return flows and calibrate this model opportunistically using local knowledge. Uncertainties may be high but not as high as is the case when return flows are the residual in water balance analysis.

BOX 5.16
Mapping and managing uncertainty

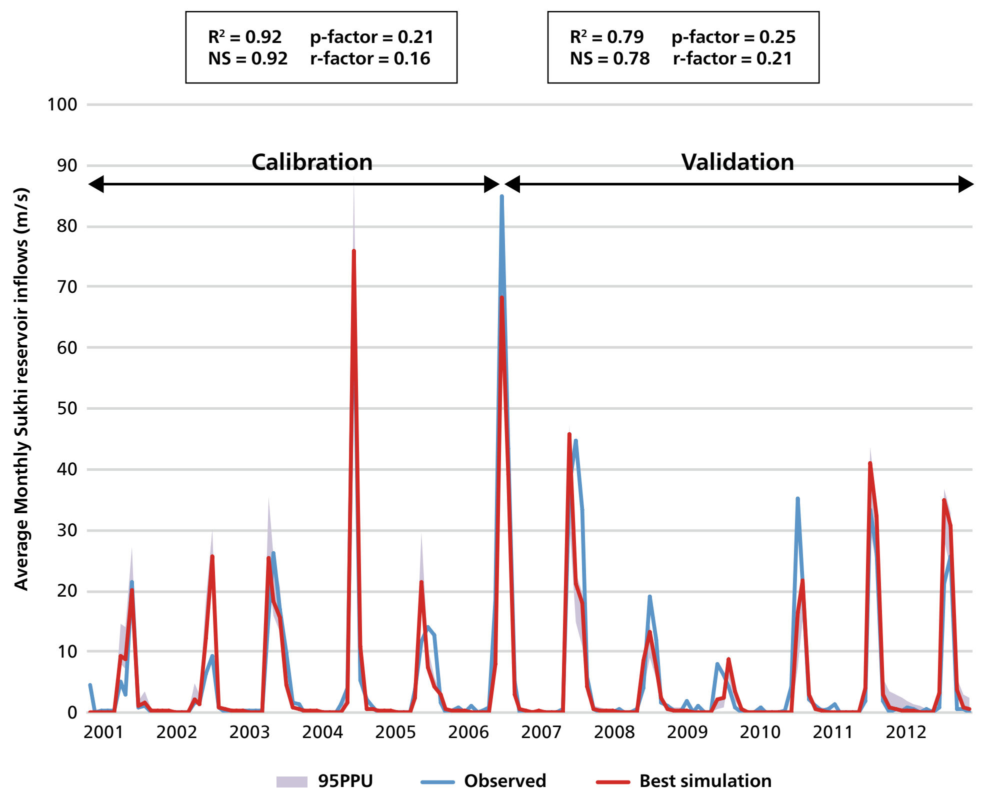
Uncertainty can be defined as a lack of knowledge about the accuracy of a measurement of a system and is an inherent property of the limitations of observing or understanding a system. Uncertainties can be classified into different types, as shown in Table 5.2. Common sources of uncertainty in water accounting (and auditing) include: lack of biophysical knowledge or understanding of the specified domain; high levels of variability of heterogeneity in biophysical characteristics in the domain and uncertainties introduced as part of the modelling process e.g. a result of scaling (see Box 5.9).

Managing uncertainty is an important part of modelling processes. This involves recognizing the sources of uncertainty and, wherever feasible, making decisions and taking steps that minimize uncertainty, if not immediately, over several cycles of water accounting (and auditing). This requires a good knowledge of hydrology and, more specifically, the limitations of hydrometric networks, remotely sensed information and the popular estimation and modelling techniques that are used. More information on handling uncertainty can be found in Section 5.7.1.

- **Default settings:** Some hydrological modelling systems provide options that can be used during set up and calibration when information is scarce. It is important to recognize that use of these default options will, in most cases, increase levels of uncertainty in model outputs.
- **Splitting observed data:** In some cases, model testing involves splitting runs of observed data into two independent periods. One period is used for calibration and the other for validation. Ideally, these periods are two time periods that encompass a representative range of rainfall and flow conditions. It is also important that there have not been any major changes in the land use or hydrological characteristics during the whole period. During the calibration period key parameters are adjusted within reasonable ranges until the best fit with the observed data is achieved. The performance of the 'calibrated' model is then tested for a separate validation period. However, it is best not to rely too heavily on a single test. If it is feasible it may be better to use a combination of approaches and independent information sources to obtain a multifaceted evaluation of model performance.
- **Sensitivity analysis** can be very useful when testing or seeking to simplify models. Through sensitivity analysis, we can identify the variables (or pairs of variables) in our model that have the greatest influence on model outputs.

Step 6: Using the hydrological model. Model selection and the results of calibration tests will have a major bearing on the potential utility of the model. More specifically, if the model testing has not shown a good agreement between observed and simulated data, it may not make sense to use it for all the uses listed below. However, if the calibration has gone well the modelling is likely to play a role in the following:

FIGURE 5.7
An example output from a model calibration or validation process that involved splitting data into two independent periods



- Quantifying water balance components (i.e. flows, fluxes and stocks) at a number of scales in time and space and supporting water balance and fractional analysis across a range of scenarios.
- Answering questions that were agreed upon with key stakeholders in Step 1 of the modelling process.
- Evaluating individual opportunities for addressing specific biophysical concerns and issues.
- Evaluating strategies as part of scenario based strategy development and more specifically the probability that a strategy will achieve all or part of a shared vision across a range of scenarios.
- Identifying and quantifying potential externalities (or perverse) outcomes that may arise as a result of adoption of a particular strategy.

Step 7: Communicate and discuss model outputs and findings with key stakeholders. Some modelling processes are rapid (i.e. completed in a few days) others can be protracted and complex. Either way, it is best to provide stakeholders with regular updates using terminology they understand. Or, put another way, the general rule is to communicate clearly and often.

If time and other resources permit, it is advisable to create an interactive version of the model and to run this during stakeholder meetings. This encourages stakeholders to engage actively with the modelling process and take ownership of the directions in which it goes. This also enables stakeholders to play an active role in in checking and interpreting model outputs.

5.5 SCENARIO BUILDING

5.5.1 Why use scenario building?

In the context of water accounting and auditing, scenario building is a methodology that can help a group of stakeholders to come to terms with uncertainty and risk in a policy development or planning process. In particular, scenarios can be used to identify the most uncertain and most important factors outside the direct control of stakeholders. Experience has shown that it is these uncontrollable factors that are more likely to disrupt plans than factors that, although very important, are predictable and under the control of stakeholders tasked with implementing policies and plans.

Key objectives of scenario building include:

- Taking good account of the inherent uncertainty and the impossibility of knowing what the future may hold in the specified domains over medium to long-term planning horizons.
- Ensuring that difficult to quantify 'governance' factors (e.g. power, trust, social cohesion, accountability, cultural values) are internalised into processes of strategy development.
- Similar to the above, ensuring that strategies take explicit account of factors (e.g. climate change, political upheaval, rising energy costs) that are outside the control of stakeholders in the water sector, but have the potential of derailing the most carefully-considered strategies.

It is important to note that scenarios are neither predictions nor forecasts, rather they are conceivable descriptions of biophysical and societal trajectories into the future based on: 1) Analysis of current and historic trends, events and processes driving change; 2) Identification of critical uncertainties, threats and challenges; and 3) Consideration of how political systems, wider society and environmental systems might respond, resolve and/or adapt to threats and challenges.

BOX 5.17

Scenario building terminology

A ***scenario*** is a plausible and internally consistent description of a possible future situation, a story about the way an area or domain of interest might turn out at some specified time in the future.

Scenario building is the process of developing scenarios.

A ***strategy*** is a medium to long-term planning framework within which specific activities are described and plans implemented. Over time, an effective strategy should lead to a vision being achieved.

Vision is a concise description of a desired future state.

5.5.2 Types of scenario building

Scenario building, as a systematic way of thinking about the future, has a long history (Swart *et al.*, 2004). However, scenario building as a methodology has not been codified into a common set of definitions and procedures. The net result is that the term scenario building is used interchangeably in relation to different types of scenario that have roots in different fields of enquiry (e.g. mathematical modelling, commerce, business management, government).

When considering different types of scenario building, a distinction can be drawn between the ***quantitative*** (modelling) and ***qualitative*** (narrative) traditions of scenario building and analysis (Swart *et al.*, 2004). Typically ***quantitative*** scenario building relies on the: 1) Development and calibration of mathematical models based on algorithms and empirical relationships that represent biophysical and societal processes and relationships in specified domains; and 2) Use of these models for testing hypotheses (i.e. 'what if' and 'what's best' analysis) and predictive analysis based on, for example, different boundary conditions[89]. This type of scenario building and analysis is appropriate when simulating well-understood systems over relatively short periods. However, for complex systems that may be poorly understood over longer-time horizons, uncertainties increase to the point that mathematical models should not be relied upon to inform decisions. This fundamental limitation of utility of ***quantitative*** scenario building and analysis means that it should, in many cases, be used in conjunction with ***qualitative*** scenario building as this may better capture other factors influencing the future such as system shifts (i.e. the non-stationarity of processes, feedback mechanisms and empirical relationships), 'black swan' events[90] or difficult-to-quantify factors such as power, trust, social cohesion, accountability and cultural values.

A distinction can also be drawn between scenario building that is: 1) Predominantly ***descriptive***, i.e. scenarios describing possible trajectories starting from what we know about current conditions and trends and 2) Predominantly ***normative***, i.e. scenarios that are constructed with a view to achieving a shared vision or a national or international norm. The word 'predominantly' is inserted here because, in practice, it is rare for scenarios to be wholly descriptive or wholly normative.

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[89] Note, that depending on the techniques used, this modelling can be either stochastic or deterministic in nature.

[90] 'Black Swan events' are those low-probability, high-impact events that are impossible to forecast or anticipate, which when they do occur can have a massive impact (Taleb, 2008).

Finally a distinction can be drawn between scenarios that are built and analysed: 1) Primarily by experts or specialists, for example, as part of a research projects or a consultancy contract; and 2) Primarily by stakeholders albeit with the support from specialists.[91]

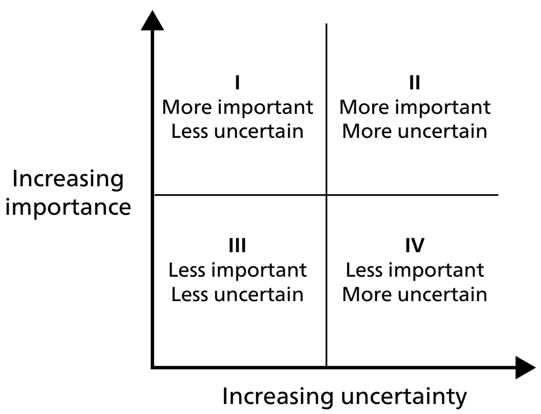
5.5.3 Scenario building: stepwise process

Although scenario building can be carried out as a stand-alone activity, it is normally used as part of a policy development or planning process. Ideally, scenario building follows the development of a shared vision and water accounting and auditing in the specified domains. As described above, there are different types of scenario building and analysis each with their own advantages and disadvantages. However, a generic approach to scenario building and analysis could follow the following steps.

Step 1: Brainstorm factors. As part of a card exercise in a stakeholder workshop, brainstorm all the factors that will affect achievement of a shared vision. This brainstorming should be wide-ranging. During this step, it is often useful to ask stakeholders to consider factors that had a bearing on the success or failure of ongoing or completed projects or programmes. At the end of this brainstorming, ask stakeholders to discuss whether some factors should be discarded on the basis that they have no relevance to the achievement of the vision, or to the specified domains.

Step 2: Separate the factors into local and external. As a continuation of the card exercise in Step 1 (i.e. using the same set of cards), separate the factors into local and external factors. Local factors are those that can be controlled or mitigated in some way by the stakeholders themselves (e.g. lack of skill or capacity can be overcome by organizing a capacity-building programme). External factors are those that are outside the control of the stakeholders (e.g. climate change, global economic trends). As the difference between local and external factors can be fuzzy, it is best not to be overly dogmatic. If it goes well, this discussion can be highly illuminating for stakeholders because it helps them to differentiate between the perceived and actual boundaries of the control that they may have over, for example, water resources, water-supply infrastructure and the delivery of water services.

FIGURE 5.8
Matrix for prioritising external factors according to importance and uncertainty



Step 3: Rank external factors according to importance and uncertainty. Using the matrix shown in Figure 5.8, classify external factors according to their level of importance and uncertainty. Permutations of factors in the upper-right quadrant (i.e. the more important and more uncertain factors) will be central to building scenarios. On the basis of discussion, it is preferable to limit these more important more uncertain factors to a manageable number (e.g. two or three), as this reduces the number of possible permutations that will be used in building scenarios. It is advisable to take time over

[91] More information on scenario building can be found in the following publications: Ratcliffe (2000); Davis (2002); Swart et al. (2004); Moriarty et al. (2007); Shell, (2008); Roxburgh (2009); Butterworth et al. (2011); Johnson et al. (2012).

this exercise because strong differences of opinion can occur. If it is facilitated well, this exercise provides an opportunity for lively discussion around these differences of opinion.

Step 4: Agree on the states of external factors. Discuss and set different future states for each of the 'more important, more uncertain' external factors that were selected in Step 3. These states should be the realistic upper and lower limits of these factors at a specified time in the future[92]. The values can be set on the basis of stakeholder perception, expert opinion, outputs from modelling, rigorous statistical analysis[93] or a combination of sources. In most cases, there is merit in adopting upper and lower limits of states that have wider government, scientific or public recognition[94].

Step 5: Create outline scenarios. Create outline scenarios by taking all possible combinations of the states of the selected external factors. To illustrate this, if two external factors have been selected, each with two states, the number of outline scenarios will be four. If three external factors have been selected, each with two states, the number of outline scenarios will be eight. However, it is common to only use two 'more important, more uncertain factors' when creating scenarios. In the likely event that stakeholders agree that more factors should be included, one approach is to create multiple two-by-two combinations of, for example, four or five factors. At the very least, this provides a basis for simplification and reducing the number of permutations to a manageable number. More positively, building and working with a number of two-by-two permutations of factors can lead to interesting discussions, stakeholder dialogue and insights (Roxburgh, 2009).

Step 6: Create narrative scenarios. A stakeholder workshop concludes with the appointment of an individual or a group of individuals that are given the responsibility of turning selected permutations or outline scenarios into narratives (i.e. narrative scenarios). This is achieved by adding a background story to each of the outline scenarios. This background story should be based partly on the less important and less uncertain external factors that were identified in Step 3. The background story should also use information that may be specific to the specified domains.

Step 7: Naming the scenarios. Select evocative and memorable names for each scenario that represent the essential logic for each scenario. Meaningful and vivid names stand a better chance of being accepted, remembered and used by stakeholders during planning processes. It is best, however, to avoid using names or descriptors such as 'good', 'bad' or 'most likely' because the strength of a good set of scenarios is that each scenario is plausible. Or put another way, all scenarios should be plausible descriptions of the future (although not necessarily equally likely to occur).

Step 8: Test and evaluate the scenarios. Review available information to check the validity of the descriptions of external factors and the values that have been given to the states of the most important and most uncertain factors. Also check that internal consistency across individual scenarios is achieved through the review of published

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92 Some scenario builders argue for 'stretch scenarios' that, for example, do not cut the tails of probability distributions. On the basis that risk and probability are not the same thing and the risk of an event is equal to its probability times its magnitude, low probability events can still be disastrous if its effects are large enough (Taleb, 2008; Roxburgh, 2009).

93 For example, analysing probability distributions relating to the factor of interest.

94 Some examples include economic growth forecasts made by the Organisation for Economic Co-operation and Development (OECD) and/or climate change forecasts detailed by the Intergovernmental Panel on Climate Change (IPCC).

information or by using modelling. Finally disseminate the scenarios to the groups of stakeholders and specialists and ask for feedback on their plausibility and validity.

5.5.4 Characteristics of a good scenario?

It can be surprisingly hard to create good scenarios (Roxburgh, 2009). Although there are many different processes that can be used for scenario building, scenarios that have the potential to improve planning process have certain common characteristics, which include:

- Scenarios are 'owned' by the stakeholders and the narratives have a local flavour.
- Scenarios have a logical structure and are internally consistent.
- Scenarios are equally plausible and build upon existing information and knowledge.
- Scenarios present information that is a mix of narrative and numerical data. As such, they can be used for specialist activities (e.g. as a basis for modelling) and non-specialist activities (e.g. as a basis for awareness campaigns).
- While the scenarios may take account of a wide-range of factors, they give particular weight to the most important and most uncertain factors that are outside the control of the stakeholders who are ultimately responsible for implementing the resulting plan.
- In the context of a planning process, results arising from scenario building are expected to challenge and inspire people to depart from 'business as usual' policies, strategies and plans that may no longer be applicable to the specified domains.
- In the context of a planning process, good scenarios always challenge and surprise – bad ones merely confirm current conceptions and perpetuate personal prejudices.

5.6 SCENARIO-BASED STRATEGY DEVELOPMENT

5.6.1 Why use scenario-based strategy development?

The main aim of scenario-based strategy development is to develop robust and adaptable strategies that have the potential to achieve a shared vision across a range of different scenarios (i.e. different futures). The main reason for using this approach to strategy development is that the resulting strategies should, compared to more traditional approaches, have a higher level of resilience to uncertain factors that may be local or external (i.e. under or outside of the control of the stakeholders). Or put another way, there should be a lower risk of strategies failing in the case of future change or events that, although improbable, may cause considerable damage and hardship.

In most cases, integrated analysis and modelling is used to evaluate the probability that components of the strategies or the overall strategies will achieve the shared vision across some or all of the scenarios. Additional reasons for using this approach to developing strategies include:

- Persuading stakeholders to think creatively about mitigating risks and threats over which they have limited control.
- Encouraging stakeholders to consider whether individual strategy components or the overall strategies are politically and socially acceptable and whether or not the risks justify any additional expenditure that might be needed.

BOX 5.18

Scenario building: challenges and tensions

A well-crafted set of scenarios encourages stakeholders to move outside the comfort and familiarity of their traditional mind-sets. In so doing a number of challenges and tensions can arise. According to Ratcliffe (2000), these include:

- Present versus future: Stakeholders, specialists and other users of the scenarios have to respect and reconcile simultaneously present realities with the logic of plausible futures. This requires a good understanding and analysis of drivers of change.
- Closed versus open-ended: Scenarios can be constructed with very specific strategy decisions in mind, or they may be developed to help decide which strategy decisions should be analysed.
- Grounded versus imaginative: Good scenarios are both thoroughly researched and thoroughly imagined, while bad scenarios rely too heavily on uninformed speculation and are poorly researched. However a balance should be struck between detailed study and unfettered creativity.
- Intellectual versus emotional: In similar vein, scenarios are necessarily an intellectual and analytical activity, but they must attempt to also capture the emotions of those who develop and implement them.
- Advocacy versus dialogue: Good scenarios are likely to be built when individuals advocate their point of view and argue the importance of different factors. However once scenarios have been selected, a more reasoned dialogue is needed among all those concerned.
- Scepticism versus expertise: Expertise is essential in the analytical process of scenario building, but because the future can be so different to the past, a healthy scepticism should be maintained in relation to the pronouncements, judgements and assessments of experts. This scepticism should also compel decision makers to reflect critically upon each scenario's logic and plausibility.
- Probability versus plausibility: One of the most contentious debates concerning the use and development of scenarios centres on the assignment of probability to the final scenarios. One school of thought argues that not assigning probabilities is a 'cop-out' because probabilities give decision-makers important information on which to base their strategies. Another school of thought asserts that assigning probabilities is a 'hangover' from the days when forecasters really thought they could predict the future.

5.6.2 Overview of the scenario-based strategy development process

At its simplest, the approach involves three phases (see Figure 5.9). First, stakeholders develop a shared vision of, for example, the water supply and water services delivery systems that they would like to see in place at some specified time in the future. Ideally the vision should be biophysical and societal in content and include measurable indicators[95]. Second, using the approach described in Section 5.5, stakeholders develop a set of plausible (although not necessarily equally likely) scenarios that describe different trajectories into the future. Third, a number of overall strategies are developed

[95] One option is to develop a vision that is SMART (Specific, Measurable, Attainable, Realistic and Timebound).

that combines various strategy components. In most cases, these strategy components will be a mix of existing practices that are working well in the specified domains and adoption of new opportunities that have been identified and evaluated as part of the water accounting and auditing process. Using integrated analysis and modelling, the potential of each strategy to achieve the vision under each strategy is evaluated.

After the first round of analysis, it may be necessary to modify some or all of the strategies and to test them again. Depending on the context and the time frame of a vision, strategies may, in practice, be simple or very complicated. A more detailed description of this process can be found in the next subsection.

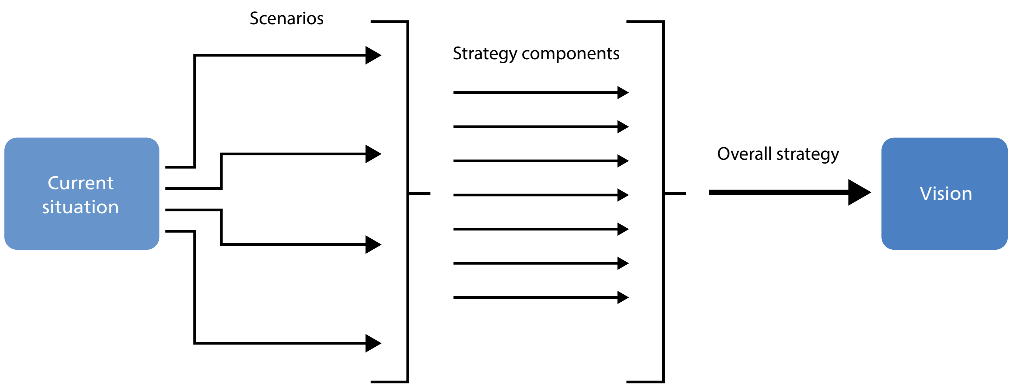
5.6.3 Scenario-based strategy development process

The following set of steps can be used to develop a strategy based on visioning and scenario building. The exact sequence of steps, number of iterations and the time that might be needed will depend on the context. If the process is to produce a robust and adaptable strategy that stakeholders can commit to, it is crucial that each step involves stakeholder dialogue that is structured around achievement of the common vision across the whole range of scenarios.

Step 1: Identify components of an overall strategy. As preparation for and/or during a multi-stakeholder platform meeting, brainstorm and list practical options and opportunities that could become components of an overall strategy that has potential to achieve the common vision. Suggestions for these strategy components may originate from many sources. Some will be based on existing practices others might be new to the stakeholders in the specified domains.

Step 2: Evaluate each strategy component. Assess the social, technical, political, economic and environmental viability and acceptability of each strategy component, especially those that are new to the stakeholders. This assessment is likely to be carried out by specialists working with stakeholders who may have a particular interest in some or all of the strategy components. The assessment should use a range of techniques (including modelling) but, regardless of the technique, specific consideration should be given to whether the strategy component is well matched, or can be adapted to the challenges and context of the specified domains. By the end of this step, a range of strategy components should have been rigorously assessed and either rejected or adapted to the specific context of the specified domain.

FIGURE 5.9
Strategy development based on visioning and scenario building



Step 3: Identify specific risks and constraints. For each strategy component selected and adapted in Step 2, identify the risks or constraints that could influence whether or not the strategy component has the potential to achieve the vision, or parts of the vision. In most cases, these factors will already have been identified and ranked as one step of the scenario-building process. If so, this 'scenario building' list of factors can be used as a starting point for carrying out this step. Finally, check whether there are risks if certain strategy components are implemented that will impact negatively on the viability of other strategy components, or on water uses and users, or the environment outside the specified domains. At the same time, attention should also be given to identifying whether particular synergies could result from implementing certain sets of strategy components as part of an overall strategy. By the end of this step, some strategy components will have been rejected, synergies between some strategy components will have been identified and the potential impacts of strategy components both inside and outside the specified domains will have been elaborated.

BOX 5.19
Robust strategies and policies

To cope with uncertainty and differences in beliefs, values, and sensitivity, policy-makers should aim for robust strategies and policies that may not be optimal in the most likely future but that lead to acceptable outcomes in a wide-range of scenarios and that are adaptive and flexible: that is, policies that are easy to revise as new information becomes available.

Source: World Bank, 2013

Step 4: Evaluate the utility of strategy components against the disaggregated vision. For each of part of the disaggregated vision, assess whether the linked group of strategy components has the potential to achieve this part of the vision across all the scenarios. Integrated analysis and modelling and other analytical techniques can support this process. The findings from this analysis should be documented or a tabulated summary made in easily accessible forms and formats that are shared with stakeholders.

Step 5: Refine strategy components. If analysis indicates that groups of strategy components are not able to achieve parts of the vision under all scenarios, try refining the group of strategy components or possibly adding strategies that are linked specifically to achieving the 'unrealised' part of the vision. If this fails, there are two possible courses of action: First, to revise parts of the vision so that it is more likely that the revised vision will be achieved. Second, to proceed in full knowledge that the vision or parts of the vision may not be achieved if some scenarios turn out to be good descriptions of the future. This second 'gamblers' option is not recommended.

Step 6: Combine strategy elements to produce versions of an overall strategy. By combining different combinations of elements, create a number of overall strategies. Continuously check that these overall strategies have the potential to achieve the vision or revised vision. Particular attention should be given in this step to the financial and other resources that will be needed, and whether effective implementation of an overall strategy will necessitate major changes in institutional arrangements and governance systems. Particular attention should also be given to, for example, evaluating whether a strategy is pro-poor and at the very least gender neutral. By the end of this step, a number of different overall strategies will have been outlined and the relative costs, benefits, merits and trade-offs of the strategies will have been tabulated.

Step 7: Select and refine an overall strategy Selection of the overall strategy should be based on stakeholder dialogue and, if appropriate, a wider consultative process. During this step, the details of the overall strategy need to be elaborated and particular attention needs to be given to issues related to environmental, institutional and social sustainability and whether life-cycle costs have been covered adequately. Finally, particular attention should be given to an integrity assessment that aims to ensure the strategy includes measures that will ensure good value for money and minimising the risks of benefits being captured by elites or other social groups.

BOX 5.20

Scenario-based strategy development: challenges and tensions

A successful strategy development process builds consensus amongst stakeholders, develops a robust and adaptable strategy and secures the support of politicians, the media and civil society. Although the concept of strategy development based on visioning and scenario building is simple, a number of challenges and tensions often arise when using this approach. These include:

- **Lack of information**: In most cases, there is insufficient good-quality information to rigorously assess all the components of an overall strategy. Collecting additional information takes time and money that may not be available. Use of adaptive management principles can help overcome this problem but even so judgements will still have to be made on the basis of expert opinion. Hence there is often a tension between those who propose more studies and those who want to move ahead quickly.
- **Evidence-based decision-making:** Strategy development in the water sector is often based on accepted wisdom, myths or folklore. The challenge in such situations is to encourage stakeholders to put their faith in evidence rather than intuition.
- **Internalising external factors:** Regardless of the approach to strategy development, important and uncertain factors outside the immediate control of stakeholders always have a high potential to derail strategies. The challenge is therefore for stakeholders, as part of the overall strategy, to seek to increase their level of influence or control over these factors.
- **Spatial and temporal scales:** In areas of increasing water scarcity, it is rare for a strategy to have no negative trade-offs. Or put another way, any changes in the way water is allocated or managed tends to result in winners and losers (in space and time). The challenge is to identify and, if necessary, minimise the number of losers, for example, by ensuring that they receive adequate compensation.
- **Acceptable levels of risk:** The methodology described here ensures that risk and uncertainty are considered during the strategy development process. However, this does not mean that the resulting strategies are devoid of uncertainty and risk. The challenge is to ensure that democratic processes are followed in reaching decisions.
- **Special interest groups:** The methodology described here encourages the active involvement of special interest groups that may be professional bodies, NGOs, or other civil society groups. While it is important that all stakeholders are represented and ‘have a voice’ in strategy development it is also important not to allow the process to be captured or dominated by one set of interests.

Step 8: Start the planning process. As the planning process progresses, new people and organizations will become involved, sometimes as part of a tendering process. As a result, new ideas may develop and flaws may be identified in the overall strategy. This may result in a requirement for some steps of the strategy development process to be repeated.

5.7 KEY CHALLENGES IN INTEGRATED ANALYSES

5.7.1 Handling uncertainty

The term uncertainty refers to a lack of sureness about something[96][97]. Levels of uncertainty can range from an almost complete lack of conviction or knowledge to near certainty. Uncertainty is also a term that is often used synonymously with: ambiguity, vagueness, imprecision and indeterminacy (Beven, 2009). But rather than worry too much about definitions of uncertainty, it is more useful to consider some typical sources of uncertainty that may be encountered during a water accounting and auditing programme (see Box 5.21).

Consideration of uncertainty is equivalent to extracting the signal from noisy data and not overestimating the information content in the data (Westerberg and MacMillan, 2015). As argued by Pappenberger and Beven (2009) and Juston *et al.* (2013), ignorance is not bliss when it comes to hydrological uncertainty; incorporation of uncertainty analysis leads to many advantages including more reliable and robust conclusions, reduction in predictive bias, and improved understanding. This is the main reason to recognize and take into account both biophysical and societal uncertainties.

A typical stepwise process for handling uncertainty in water accounting and auditing is outlined in Figure 5.10 and described as follows:

Step 1. Identification of uncertainties

The aim of this step is to identify and list the main sources of uncertainty during each cycle of water accounting and auditing. Note it is not recommended that all sources of uncertainty are listed because: 1) All the information acquired, analysed, modelled is subject to some level of uncertainty and 2) The process of handling and managing uncertainty, to be viable, should not require or use a disproportionate amount of time and other resources that may be available.

The sources of uncertainty are inherent in water accounting and auditing are generic and predictable (e.g. relating to uncertainties of measurement) while others are specific to the domains of interest. Using checklists can be helpful particularly when identifying generic sources. It is notable also that some sources of uncertainty are quantitative in nature (e.g. measurement uncertainty) while others are qualitative (e.g. uncertainty in factors of political economy). Important sources of uncertainty that are qualitative in nature should be identified, listed and documented.

[96] This definition of uncertainty is based on the one presented in the United Nations World Water Development Report (WWAP, 2012).

[97] The terms uncertainty and risk are often used interchangeably. From a water accounting and auditing perspective, it is important to recognize that, although these terms are related, they have different meanings which can be summarised as: "When the chance or probability of an outcome is known in advance this is called risk. When the chance of an outcome is not known in advance this is called uncertainty" (Kahan, 2008).

Sources of uncertainty relate equally well to water accounting and auditing and they occur during all stages and cycles of a water accounting and auditing process, for example, when:

- framing issues and opportunities;

BOX 5.21

Some typical sources of uncertainty

Uncertainty encountered during water accounting and auditing programmes for example can be associated with:

- Inadequate or poorly-maintained hydrometric networks.
- Non-stationarity of hydrological processes e.g. relating to the severity and frequency of floods and droughts.
- Incomplete understanding of drivers of change e.g. relating to faming and water management systems.
- Ability of societal systems to adapt and cope with external drivers e.g. related to linear or non-linear impacts of climate change or macro-economics.
- Lack of understanding of societal and biophysical feedback loops e.g. relating to unsustainable use of natural resources (in space and time).
- Lack of knowledge or understanding e.g. regarding the benefits and/or externalities linked to new agricultural or water management policies and practices.
- Regionalising point measurements e.g. upscaling observations of rainfall at one point to volumes of water falling over a nearby or a distant catchment area.
- Estimation of hydrological variables that cannot be measured directly e.g. evaporation, groundwater recharge.
- Water quality data e.g. as a result of poor sampling techniques or failure to follow protocols when handling and analysing water samples.
- Quality control procedures e.g. when quality control procedures filter out suspect data that could be real and an important signal of change.
- Poorly maintained statistics or official records e.g. when a government, utility or contractors manipulate figures to show that norms or targets have been achieved.
- Lack of information on the functionality of water supply infrastructure e.g. inequitable distribution of water as a result poor maintenance, lack of metering or illegal connections.
- Perceptions (or mental models) that institutions or people have of hydrological processes or the benefits of different land management practices e.g. potential disconnects between accepted wisdom
- Aggregation or disaggregation of empirical information to a scale that is more relevant to analysis or decision-making.
- Gaps in understanding of the political economy of how decisions are made or mediated at different institutional levels.

Note that this list is far from being exhaustive.

- acquiring, quality controlling and processing primary and secondary information;

- aggregating, disaggregating, extrapolating or regionalising information;

- analysing, modelling and interpreting information;

- generating and sharing outputs, other findings and recommendations;

- communicating information (including information relating to uncertainty) and

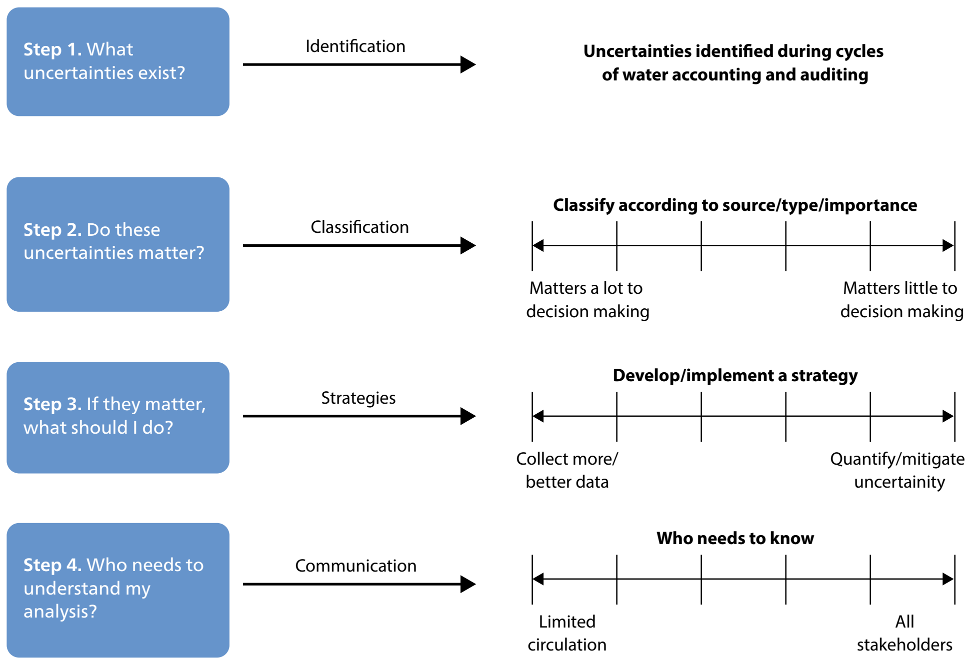
-developing and implementing theories of change relating output to outcome pathways.

Step 2: Classification of uncertainties according to type/importance

The aim of this step is to classify the sources of uncertainty according to the type and levels of importance:

- **Different types of uncertainty:** Sources of uncertainty identified, listed and documented during Step 1 are separated according whether or not the uncertainties are epistemic and aleatory[98]. This will help identify uncertainties that are reducible as part of the water accounting process and uncertainties that are irreducible that may need to be mitigated and/or quantified.

FIGURE 5.10
Stepwise process for handling uncertainty



Source: EPA, 1999

98 While many sources of uncertainty may exist, they are generally categorized by modellers as either epistemic or aleatory. Uncertainties are characterized as epistemic, if the modeller sees a possibility to reduce them by gathering more data or by refining models. Uncertainties are categorized as aleatory if the modeller does not foresee the possibility of reducing them (der Kiureghian and Ditlevsen, 2009). For the record, some authors have argued that the classification of uncertainties is not really necessary and that there are only epistemic uncertainties arising from lack of knowledge relating to, for example, hydrological processes (Beven, 2015).

- **Level of importance:** The lists of sources and types of uncertainty generated above (and updated during each cycle of water accounting and auditing) is in itself a short list of the main sources of uncertainty, given that the aim of Step 1 is not to produce an exhaustive list. The aim here is to shortlist uncertainties that are likely to influence: 1) Outputs from the water accounting and auditing process; and 2) Decisions that may be made on the basis of these outputs. An important point here is that uncertainties take on significance relative to a decision being made and the timing of the process of that decision. At certain times, uncertainties can have limited significance but at a later stage in a decision-making process they can assume greater importance. Clearly the magnitude of uncertainties and the societal and biophysical context can also influence their significance
- Sensitivity analysis can play a role in assessing the level of importance of different sources of uncertainty particular in relation to different variables considered during analysis and modelling. Simulation analysis can be used to determine the sensitivity of computation or model outputs to different input parameters. by performing computations or model runs using default parameter values and then varying them within the upper and lower limits established according to the characteristics of each parameter. In the case of hydrological modelling, the use of sensitivity analysis can be used to identify the most important parameters required to model the hydrological processes in specified domains (e.g. da Silva *et al*., 2015). In terms of HEMs, even relatively crude sensitivity analysis can be useful and informative (Jakeman *et al*. 2006).

Step 3: Development and implementation of an 'uncertainties' strategy

The aim of this step is to develop (or update) and implement a strategy for handing uncertainty and, more specifically, focus on the shortlist of sources or types of uncertainty that has been produced during the Steps 1 and 2. Box 5.22 lists actions that could form part of a strategy. Guidelines are also freely available on the web[99].

TABLE 5.2
Mapping and managing types of uncertainty

Aleatory uncertainty **(also known as systemic uncertainty)**	Quantifiable and irreducible	Heterogeneity Fuzziness	That which we know (and include or don't use)
	Quantifiable and potentially irreducible	Randomness Inexactness	
	Quantifiable, potentially irreducible, maybe irrelevant	Variability Imprecision	
	Quantifiable and potentially reducible	Incompleteness Active ignorance	That which we know we don't know
		Inconsistency Conflict	That which we can't agree that we know
Epistemic uncertainty **(also known as statistical uncertainty)**	Unquantifiable but potentially reducible	Incompleteness Passive ignorance	That which we know we don't know
	Unknowable and irreducible	Incompleteness Indeterminacy	That which we could not possibly know

Source: Curtis and Wood, 2004

[99] See e.g. the uncertainty guidelines in NEWATER (2009).

Monte Carlo (MC) techniques are increasingly used to evaluate the uncertainty in predictions arising from uncertainty in model input parameters and to estimate the confidence that should be assigned to modelling results. The approach typically involves running a deterministic model repeatedly for a large number of input values sampled from statistical distributions[100].

From a hydrological perspective, the need for more rigorous uncertainty analysis is now widely accepted and the emphasis of discussion is on the most suitable techniques to use (Hrachowitz *et al*., 2013)[101]. In the past two decades, the GLUE Generalized Likelihood Uncertainty Estimation[102] (GLUE) methodology has had widespread application and use in model parameter and predictive uncertainty analysis (Sadegh and Vrught, 2013). It is notable, however, that in recent years a protracted debate has emerged between proponents that adhere firmly to the underlying philosophy of GLUE and believe that it is a proven and useful working methodology and those who consider that formal (Bayesian) statistics is more likely to produce an objective estimate of uncertainty. (Sadegh and Vrugt, 2013, Beven, 2015). While this debate continues and new approaches are being developed and tested[103], it is unlikely that a universal approach or code of practice for estimating hydrological uncertainties will emerge. This state of affairs, however, should not be used as an excuse for not analysing uncertainty or not being quite clear about the assumptions made when producing a particular uncertainty estimate (Beven, 2015).

Step 4: Communication of uncertainties

The aim of this step is to ensure that information relating to uncertainties is communicated to partners, stakeholders and the wider public as and when required by them. Strategies will be needed to communicate uncertainties in forms that are easily accessible and that do not inadvertently undermine the recommendations, strategies and other outputs from water accounting and auditing. At this point, it is important to note that many users of the water accounting and auditing outputs much prefer those in the form of unambiguous clear-cut statements. The challenge of handling uncertainty is often exacerbated by the fact that many environmental and social scientists and engineers are reluctant to recognize the importance of uncertainty let alone to estimate and manage it[104]. Hence, often a first step is to raise the awareness of uncertainty with everyone who is directly involved in a water accounting and auditing programme and to draw their attention to some practical steps to take to identify and mitigate sources of uncertainty.

From a decision-maker's perspective, the issues relating to, for example, hydrological uncertainties are often even more acute and problematic (Beven, 2015). If, even with a detailed, and expensive, assessment of uncertainty, there is the potential for surprise or being wrong, it is necessary to be cautious when making robust decisions about the future. It is also significant that, adoption of the precautionary, principle usually involves higher levels of expenditure. Hence, the challenge for those responsible for communicating outputs from water accounting and auditing include:

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[100] See e.g. the use of MC techniques as part of a water accounting study in Ethiopia (Karimi, *et al*., 2015).

[101] See e.g.

[102] For more information on the GLUE methodology see Beven and Binley (2014).

[103] For example, the Approximate Bayesian Computation approach and applications (Sadegh and Vrugt, 2014; Vrugt, 2016)

[104] Beven (2009) lists some of the reasons why environmental scientists tend not to use uncertainty analysis.

BOX 5.22

Some practical recommendations for handling and/or taking better account of uncertainty

- Seek to reduce 'reducible' uncertainties and to mitigate or quantify 'irreducible' uncertainties iteratively during each cycle of water accounting and auditing.
- Collect more or better information.
- Initiate studies that improve understanding of dominant biophysical and/or societal processes and feedback mechanisms.
- Develop protocols that minimise/eliminate subjectivity in, for example, information management, analysis and interpretation.
- As a general rule, give more credence to empirical information (i.e. information that can be verified by observation and first-hand experience) than, for example, accepted wisdom or expert opinion.
- Use scenario-based analysis or strategy development as an part of strategy development.
- Rigorously cross-check and triangulate evidence and findings.
- Where appropriate present the findings, outputs and forecasts from water accounting and auditing in the form of ranges or probability distributions.
- Use sensitivity analysis to identify uncertainties that have the most influence on priority outputs or outcomes.
- Take an adaptive and iterative approach to piloting recommended strategies or approaches.
- Use statistical methods such as GLUE (or other Monte Carlo techniques for quantifying the uncertainty of model predictions (for more information on GLUE see Beven, 2009).
- Consider using Bayesian inference as a means of updating probability estimates as additional evidence is acquired (Silver, 2012).

- Making the affirmative case for taking uncertainties into account when making decisions (e.g. a higher likelihood of positive outcomes).
- Communicating the uncertainties as unambiguously as possible.
- Following an agreed protocol or strategy for communicating uncertainties so as to not confuse the target groups.
- Making use of interactive visualisations.
- Taking account of lessons learned[105].

[105] For example see Innocent (2013): http://blogs.lse.ac.uk/impactofsocialsciences/2013/07/22/making-sense-of-uncertainty-sense-about-science/

5.8 TIPS AND TRICKS

5.8.1 On information management

- If sufficient resources permit, include an information manager in the water accounting and auditing team. If this is not possible, ensure that at least one team member has good information management skills and experience.
- Don't use information technology that does not fit well with the requirements and capacities of partners, key stakeholders and anyone directly involved in the water accounting and auditing process.
- Recognize there is a risk that quality control procedures may reject information that is valid and interesting.
- Recognize that stakeholders may be reluctant to share information that is politically, commercially or professionally sensitive.
- Be wary of information that is based on self-reporting because organizations responsible for implementing policies and programmes have a vested interest in accentuating the positive aspects of these policies and programmes.
- Track and utilise data and information from organizations and individuals that have a reputation for collecting and supplying good quality information. Conversely avoid organizations that prove to be, or are known to be, unreliable;
- Try to create a culture of valuing information and constantly striving to improve the quality of information within a water accounting and auditing team.
- In some cases, it is necessary and pragmatic to plan information acquisition on the basis of availability and accessibility rather than preferred indicators.
- As a general rule, give more weight to empirical information or evidence, as opposed to derived or simulated information, anecdotal evidence or expert opinion.
- Try to collect or download available secondary data (and metadata) at the beginning of a cycle of water accounting and auditing because gaining access to some datasets may take some time.
- Avoid being too ambitious, especially in terms of the spatial and temporal resolution of the modelling. Higher resolution provides more detailed outputs but also increases the model run time and the size or detail of the outputs that in turn may make analysis and interpretation more difficult and time consuming.
- Leave plenty of time for model calibration and validation. The risk is that by allocating a disproportionate amount of time and effort to collecting/processing data and setting the model up insufficient time and other resources will be available for model calibration and validation.
- Document modelling processes in detail, especially when using complex models.
- Although the utility of HEMs is improving, it may be advisable to use HEMs for research-type studies or investigations and integrated approaches to modelling (e.g. Bayesian networks or agent-based models) to complement and supplement hydrological modelling.
- Given the levels of uncertainty, most outputs and recommendations from water accounting and auditing should be qualified and, where relevant, presented probabilistically.

- Some extreme events or combinations of extreme events are unknowable and, by definition, these will not be identified by analysis of past events or historic trends or by scenario building.[106]

[106] In terms of strategy development, Taleb (2012) suggests that, rather than trying to predict 'unknowable' events, it is better to build robustness, resilience or 'anti-fragility' into systems.

6. OUTPUTS AND OUTCOMES

6.1 AIMS OF THIS SECTION

The rationale behind this sourcebook is that evidence-informed sectoral and inter-sectoral decision-making based on water accounting and auditing has the potential to produce desired outputs, outcomes and impacts. However, we know that moving from outputs to outcomes and impacts is rarely a linear process not least because facts and evidence are often ignored or rejected if they threaten the status quo.

The aim of this section is to highlight some of the challenges of moving from outputs to outcomes. Communication is central to this process but, at a deeper level, behavioural economics, politics and gaps between water belief systems and scientific knowledge can all play an important role in determining what happens, or doesn't happen, as outputs are transformed into outcomes and impacts.

While most attention is given to communication, this section describes the other activities that a typical water accounting and auditing programmes use to improve the likelihood of outputs contributing to positive outcomes and impacts such as active stakeholder engagement, social and institutional learning, a focus on priority issues and concerns and so on. Other activities are listed that can be used in parallel with water accounting and auditing with a view to increasing the likelihood of desirable outcomes.

It should be noted that outcomes and outputs are placed at the end of the water accounting process (See Figure 1.3) in part because this is when particular attention is given to the cyclical process of turning outputs into outcomes. However, the process itself should start ideally during the water accounting and auditing inception phase with activities such as engaging actively with stakeholders or preparing and implementing a provisional communication strategy.

BOX 6.1

Relevant output-outcome terminology

Outputs are the products and services that result from a programme of water accounting and auditing that are necessary to achieve its objectives. Outputs can also represent changes in skills or abilities or capacities of individuals or institutions.

Outcomes are the intended or achieved short-term and medium-term effects of the outputs of the water accounting and auditing programme. Outcomes include externalities and trade-offs within or outside specified domains.

Impacts are the positive and negative long-term effects on water users or uses (in space and time) of strategies or interventions. These effects can be societal or biophysical in nature.

Source: Bester, 2012

6.2 MOVING FROM OUTPUTS TO OUTCOMES

All too often water accounting and auditing type programmes are designed and implemented on the basis that key stakeholders in the specified domains are, when it comes to making important decisions, suffering from an information deficit. The logic is that all that is needed to overcome this deficit are better decisions and better outcomes and impacts will follow. In some cases, this logic may be correct but in most cases it is not as simple. Hence the approach to water accounting and auditing recommended here is built around activities and approaches that include:

- **Stakeholder engagement:** By using the stakeholder engagement model, key stakeholders are actively and intimately engaged in water accounting and auditing activities including the interpretation of findings and formulation of outputs. The net result is that stakeholders should have more ownership of outputs than would the case with the standard transfer of information model.
- **Multi-scalar and multi-institutional level analysis** is a fundamental requirement of water accounting if, for example, return flows are to be correctly identified and quantified. Strong support for outputs across institutional levels is also essential to provide legitimacy and to improve the likelihood that outputs are transformed into outcomes. In particular, without support and commitment at the middle-management levels, proposed changes in, for example, governance processes, run the risk of merely becoming an administrative exercise rather than a reality.
- **A focus on issues and concerns of high political and public importance:** Typically water accounting and auditing is planned and implemented in a series of iterative cycles that identify and focus increasingly on priority issues and opportunities in specified domains. With each cycle, information acquisition and analysis is better targeted, more detailed, more multi-scalar and more interdisciplinary. As a result, recommended strategies and other outputs are likely to have a high relevance and not be peripheral or isolated from political and social priorities.
- **Social and institutional learning:** Multi-stakeholder processes, iterative cycles and a focus on priority issues and concerns are all central elements of the recommended water accounting and auditing process. These activities create many opportunities for social and institutional learning that increase the knowledge and capacity of key stakeholders. In addition social and institutional learning can contribute to narrowing possible gaps between water belief systems and scientific knowledge. These activities also contribute to better ownership of and confidence in the outputs of a water accounting and auditing programme.
- **Thinking politically and working differently:** Water accounting and auditing provides a balanced approach: 1) For analysing priority issues and concerns in the specified domains from both biophysical and societal perspectives; and 2) Evaluating opportunities for addressing issues and concerns that may be biophysical, societal or a mix of both. More specifically, the outputs of this approach address questions such as: Is change feasible or politically and socially acceptable?
- **Evidence and scenario-based based strategy development and evaluation:** Water accounting and auditing in the specified domains provides a sound biophysical and societal good starting point for strategy development, adaptation or evaluation based on visioning and scenario building. If all goes to plan, the outputs are strategies that: 1) Are well adapted to the biophysical and societal context; and 2) Have the potential to achieve a shared vision across a range of different scenarios (i.e. different futures).

6.3 COMMUNICATION

6.3.1 Role of communication

Communication is a process that enables key stakeholders to engage with each other, with the wider public and with organizations that have the responsibility for carrying out water accounting and auditing at different institutional levels. In the context of water accounting and auditing, communication is understood to be more than exchanging and sharing information, knowledge, experience and views. It also involves debate, negotiation and joint learning that over time has the potential to build trust and social capital. If all goes well, effective communication provides a solid basis for evidence-informed decision-making and a shift away from decisions that are based on anecdotal evidence, expert opinion or intuition.

Effective communication empowers decision-makers at every level to make better choices. However, specialists like to believe that: 1) Individuals and organizations make rational decisions based on an assessment of facts and evidence; and 2) All that has to be done to persuade individuals and organizations to change what they are doing and try something new is to communicate the relevant information (e.g. from water accounting and auditing or similar). However, experience and a host of psychological experiments have shown that it doesn't work like this. Instead of being rational, humans tend to accept information that confirms their cultural values, and reject information that conflicts with their cultural values (Crompton, 2010). The simple fact is that individuals and, to some extent, organizations tend to mould their thinking around their social identity, protecting it from serious challenge.

BOX 6.2
Rational decision-making?

There is increasing evidence, which has built up over many decades, that people are often far from rational or deliberative when making judgements or choices. From its survey of the literature, the World Bank's 2014 World Development Report concludes that:

- people make most judgments and most choices automatically, not deliberatively;
- how people act and think often depends on what others around them do and think rather than facts and evidence.

Source: World Bank,2013; de Waal, 2015

Communication is an integral and necessary component of every phase and cycle of water accounting and auditing. In part, because it ensures that key stakeholders are fully informed and able to provide timely feedback to those responsible for the water accounting and auditing and, in part, because it reduces the risk that the interests of key stakeholders might dwindle or that they might be unduly surprised or inconvenienced by the findings or insights that emerge. To be effective, communication should keep stakeholders informed on what is being done, where and by whom. Communication should also be timely and call for feedback on whether or not the process is on track and owned by stakeholders. As important, a good communication strategy identifies and seeks to mitigate asymmetries in the access of key stakeholders and ordinary citizens to facts, evidence, knowledge and recommendations.

BOX 6.3
Risk of flying blind

Well-organised communication is a key element of effective water accounting and auditing. Unless stakeholders are actively engaged and well informed, they will have limited interest in participating in water accounting or auditing processes and/or making use of findings and other outputs. As important, in the absence of good communication, water accounting and auditing will be "flying blind" in terms of delivering findings, outputs and recommendations that are acceptable to and meet the needs of key stakeholders and the wider public.

BOX 6.4

More or better communication?

It is sometimes assumed that we need more communication of outputs within the international development field. This is not necessarily true. More communication can simply end up as a form of 'pushing knowledge down a hosepipe, in the hope that at least some of it will come out the other end'. The reality is often what we need is far better communication of outputs.

Source: Hovland, 2005

6.3.2 Communication that prompts desired change

Often, water professionals see communication solely in terms of information transmission in the form of rather dense technical reports. If the target audience fails to respond in the way the professionals believe they should, the professionals believe there has been a problem in finding the right words or possibly in teaching the target audience the meanings of the terminology used (Green, 2011). The reality is that individuals and organizations reject information that could do them harm or could put them on the other side of an argument to more powerful individuals or groups. Also individuals and organizations tend to reject facts and evidence because:

- It does not conform to their cultural values, accepted wisdom or social identity.
- It does not conform to a prevailing sanctioned discourse[107].
- It may embarrass them in the eyes' of their peers and/or make them look weak.
- It may devalue the work that has been a source of considerable pride over a long period.
- It could harm their future employment prospects in some material way.
- It could close down opportunities for rent seeking or other dubious practices.

The above poses a serious problem for water accounting and auditing that often, especially in areas of increasing water scarcity, produces outputs that are rejected by stakeholders for the reasons given above. In terms of communication, one option is to stick with the standard transfer of information model and assume that, one way or another, facts supported by a large body of peer-reviewed evidence will always win out if not now, at least at some time in the future. The alternative is to develop and implement a communication strategy that recognizes the risk that stakeholders may reject important outputs or, even worse, that outputs may actually harden resistance and increase the tendency of stakeholders to support alternative arguments (Crompton, 2010).

One option is to use the stakeholder engagement model, whereby key stakeholders are actively and intimately engaged in water accounting and auditing activities including the formulation of outputs. Even though some outputs may not be palatable, stakeholders will have more ownership of outputs than would the case with the standard transfer of information model. It is likely also that they will have more time: to absorb and internalise outputs; to come up with strategies for mitigating any negative impacts that these outputs may have; or to come up with strategies that enable them to benefit from using the outputs to prompt change.

[107] A sanctioned discourse is a particular view or opinion that is politically acceptable at a specific point in time. To disagree with or challenge this view or opinion could come at the cost of exclusion from the groups that have the power to damage careers or sanction individuals or organizations in one way or another (Zeitoun and Warner, 2006).

Another option is to work with individuals and organizations that have professional communication skills and the capacity to be creative, upbeat and inspirational in terms of new visions of what could and possibly should be achieved in the specified domains. This could lead to communication activities that include:

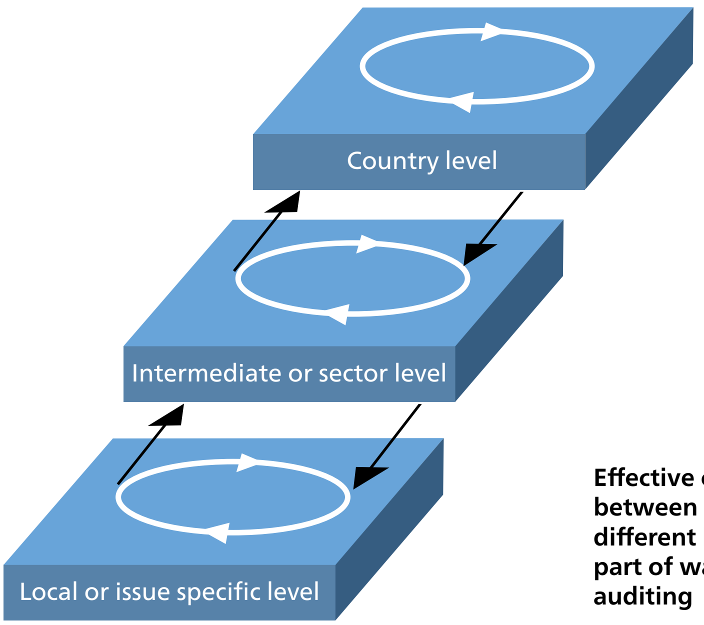
- Using segmentation and targeting tools developed by the marketing industry to separate groups according to the reasons that they might reject or accept water accounting and auditing outputs.
- Tailoring communication methods, including social media, products such as infographics and messages to these groups.
- Using, as far as possible, affirmative messages that are built around the core values of groups rather than messages that are inherently negative or critical.
- Developing interactive visualizations that, for example, make it possible for stakeholders to explore potential impacts of interventions in specified domains on water users and uses (in space and time).
- Building coalitions with key stakeholders who are sympathetic to the accounting and auditing outputs.

BOX 6.5
Facts and evidence

In the water sector, facts and evidence are often regarded as being intrinsically technical, quantitative and the basis for simply deciding which interventions work (or don't work). However, in the context of water accounting and auditing, facts, evidence and analysis form the basis of understanding and learning around the reasons why interventions and approaches may work in one context but not another. In many cases, this evidence-informed approach reinforces the fact that many factors may enable or constrain the success of reforms. These are just as likely to be political and economic as they are technical or biophysical.

Source: Whitty and Dercon 2013

FIGURE 6.1
Inter- and intra-level communications



Effective communication between stakeholders at different levels is an important part of water accounting and auditing

TABLE 6.1
Role of communication in water accounting and auditing

What communication can do	What communication cannot do
Inform debate and dialogue at all levels	Be a substitute for a political process, capacity building, institutional development or a change management process
Contribute to social learning via dialogue and sharing of views, experiences and knowledge	Guarantee consensus and/or a convergence of views, beliefs and values
Help build and maintain active stakeholder engagement throughout the water accounting and auditing process	Convince all those with a vested interest in the status quo to support the water accounting and auditing process or the findings and outcomes
Rally stakeholders around a credible, relevant, and compelling message	Act as a substitute for well-respected champions, opinion formers or leaders
Use credible evidence to change mind-sets and persuade stakeholders	As a stand-alone activity, overcome deeply seated beliefs, social values and/or irrational support for certain policies or practices
Ensure that water accounting and auditing takes account of stakeholders needs and views	Cover up the fact that the views of some stakeholders may be unfounded, based on misunderstandings and anecdotal evidence
Make complex information available in forms and formats that are interesting and easily accessible	Convert stakeholders and the wider public into specialists
Help tackle stakeholder asymmetries relating to access information and influence	Improve the power, confidence, capacity and ability of marginalised social groups
Manage expectations and allay fears	Guarantee that some stakeholders will not selectively use water accounting and auditing outputs to raise expectations and/or to gain political advantage
Draw attention to poor performance of current policies and practices and to potential unintended consequences (i.e. externalities)	Guarantee that facts and evidences will not be rejected
Establish platforms, fora etc for feedback from and relevant dialogue with and between stakeholders and the wider public	Control the level of interest or the direction in which this dialogue may go

Source: Chaman et al., 2012

6.3.3 Communication: what it can and cannot achieve

Communication strategies are often blamed when key stakeholders and the wider public are unmoved by the findings or recommendations of water accounting, water auditing or similar activities. There are however limits to the potential impact of even the best-designed communication strategy and the most conscientious implementation of this strategy. The list of what can be achieved is impressive (see Table 6.1). However Table 6.1 also gives an indication of outcomes or activities that are unlikely to be achieved by communication alone.

6.3.4 Communication: influencing policy and practice

Whilst communication includes the routine formal and informal sharing or exchanging of information, it can and should also involve: 1) Fostering social awareness and facilitating stakeholder and public democratic dialogue; 2) Underpinning evidence-based policy formulation; 3) Building a shared understanding which can lead to social change; 4) Creating space for the voices of the poor to be heard; and 5) Mitigating asymmetries in power and control. However, these positive effects of communication do not come automatically (CommGAP, 2009b). In fact, in certain situations, lack of communication or oversights can dramatically hinder a water accounting and auditing process, for example, when a key stakeholder is annoyed by the fact that he or she has not been invited to attend and/or give a presentation at an important workshop.

As stated earlier is this section, facts and evidence are often of limited value in influencing people's opinions and judgement (Crompton, 2010). This said, factual accuracy should be an ethical, professional and practical imperative for everyone directly or indirectly involved in water accounting and auditing. Alone, however, facts or evidence relating to, for example, the effectiveness of a policy are often ineffective in motivating political and public concern and behaviour commensurate with the magnitude of the problem that may have been unearthed. Presentation of facts can even prove to be counter-productive. The cognitive scientist George Lakoff highlights the dangers of assuming that if people know the facts, they will accurately identify where their self-interest lies, and act in line with these interests (see Box 6.6).

There is also considerable evidence that, rather than being influenced by facts and evidence, people tend to take their cue on what they should feel and believe from their own social group or community leaders. In addition, groups with opposing beliefs and values will often interpret the same new information in a way that reinforces their beliefs (Monbiot, 2010). The net result is that rather than converging when presented by compelling new evidence, opposing viewpoints become more polarised.

This rather negative view of the potential impact of facts and evidence on the beliefs and behaviour of decision makers presented above is counter-balanced, to some extent, by the experiences of sectors that have shifted from decision-making based on anecdotes and expert opinion to decision-making based on or informed by solid evidence. It is argued that the consequences of moving from opinion such as expert opinion, received wisdom or anecdote-based, to evidence-based healthcare policy have been spectacular. To quote an Economist headline[108], "Africa is currently experiencing some of the

BOX 6.6

Enlightened reason

The principle of enlightened reason suggests that:

> *"If people are made aware of the facts and figures, they should naturally reason to the right conclusion. Voters should vote their interests; they should calculate which policies and programs are in their best interests, and vote for the candidates who advocate these policies and programs"* (Lakoff, 2009).

But the practice of many of the most effective politicians, and the understanding of cognitive science, paints a different picture:

> *"Voters don't behave that way. They vote against their obvious self-interest; they allow bias, prejudice, and emotion to guide their decisions; they argue madly about values, priorities, and goals. Or they quietly reach conclusions independent of their interests without consciously knowing why. Enlightenment reason does not account for real political behaviour because the Enlightenment view of reason is false"* (Lakoff, 2009).

Source: Crompton, 2010

[108] See http://www.economist.com/node/21555571

fastest falls in childhood mortality ever seen, anywhere". The contention of Whitty and Dercon (2013) is that this success is based on many small bits of evidence, from many disciplines, leading to multiple incrementally better interventions[109]. Critically, it also involves stopping doing things which the expert consensus agreed should work, but when tested do not. Whitty and Dercon (2013) also argue that it is no accident that the health sector, which is a sector that is adopting evidence-informed approaches, is also one where recent development efforts have had some of their greatest successes.

Politicians are particularly adept at influencing people to change their minds and or to behave differently. For example, approaches taken in political communication are central to efforts to reform governance systems (CommGAP, 2009b). There are two broad reasons for this:

- The first is that if you want to influence or change the way a society is governed. You can use political power (or even political force) or you can manipulate incentives. Failing that you have to persuade (CommGAP, 2009b);
- The second is that the sustainability of change depends on persuading people to take ownership of and internalise the change itself. As a result, those involved

BOX 6.7

Confident communication

Most executives rightly feel a need to take action. However, The actions they take are often prompted by excessive optimism about the future and especially about their own ability to influence it. To make matters worse, the culture of many organizations suppresses uncertainty and rewards behaviour that ignores uncertainty. For instance, in most organizations, an executive who projects great confidence in a strategy is more likely to get it approved than one that lays out all the risks and uncertainties associated with a particular strategy. However people seldom recognize excessive confidence as a warning sign.

Source: Lovallo and Sibony, 2010

BOX 6.8

Dual-process model of the human brain

There is increasing consensus that human brains have two fundamentally different modes of thought:

- **System 1** is fast, intuitive, associative, metaphorical, automatic, impressionistic, and it can't be switched off. Its operations involve no sense of intentional control, but it is the "secret author of many of the choices and judgments you make".
- **System 2** is slow, deliberate, and effortful. Its operations require attention. System 2 takes over, rather unwillingly, when things get difficult.

System 2 is slothful, and tires easily – so it usually accepts what System 1 tells it. It's often right to do so, because System 1 is for the most part pretty good at what it does; it is highly sensitive to subtle environmental cues, signs of danger, and so on. It does, however, pay a high price for speed. It loves to simplify, to assume WYSIATI ("what you see is all there is"), even as it gossips and embroiders and confabulates. It is hopelessly bad at the kind of statistical thinking often required for good decisions, it jumps wildly to conclusions and is subject to a fantastic suite of irrational biases.

Source: Kahneman, 2011

[109] See www.thelancet.com/journals/lancet/article/PIIS0140-6736(12)61376-2/abstract

in promoting or instigating change have to understand that whatever other business they think they are in they are also in the persuasion business.

Political strategist and advertising or marketing agencies are experts in the art of persuasion and, more specifically how to influence opinion, attitudes, and behaviour. In recent years, the concept of 'nudging' has gained traction in political circles[110]. The idea that people can be 'nudged' into new forms of behaviour is built on the premise that we are not rational beings and that our brains have two modes of thought [111] (see Box 6.8).

The first of these modes (i.e. System 1) is particularly susceptible to being nudged into a thought or an action that is irrational. The fact that political strategists or others with excellent communications skills can mould our minds raises profound ethical questions. It is notable also that System 1 thinking and decision making is often based on anecdotes, intuition and/ or received wisdom whereas System 2 thinking and decision-making is more likely to be informed by careful consideration of facts and evidence.

BOX 6.9

Relative importance of communication

Across the development sector there has been a long-standing tradition of thinking of communication as a secondary activity. Development issues are regarded as being urgent, complex and a high priority. In contrast, communication initiatives often end up being tacked on as an afterthought to be carried out by people who may or may not have professional experience in this field. But in communication, as in any other endeavour, this kind of poor planning and resourcing yields poor results and missed opportunities.

Source: UNDP, 2013

Clearly there is a case for using communication to nudge individuals and or organizations to take decisions that are for the greater good of society as a whole (and backed up by reliable facts and evidence). However, this argument breaks down if and when nudging is used to benefit 'big business', elites or other social groups at the expense of, say, poor and marginalised social groups or rare and important aquatic ecosystems. This said, coercive communication cannot easily be legislated against and, as a consequence, it is inevitable that all communication, campaigns and policies will be targeted as much at *how* we think as *what* we think.

BOX 6.10

Components of a communication strategy

1. What are you trying to do?
2. What are the potential threats and opportunities?
3. Who needs to communicate with whom?
4. What do you want to say to internal and external audiences?
5. How do you reach your audience?
6. Who does what, when and how?
7. Paying the bills
8. Evaluating results

Source: UNDP, 2013

6.3.5 Preparing a communication strategy: getting started

While the main responsibility for communication may rest with the implementers of a water accounting and auditing process or programme, it is likely that many, or possibly all, activities will

110 Thaler and Sunstein (2008) played a significant role in popularising the 'nudging concept.

111 These two modes are referred to as 'System 1 and System 2' and 'Automatic and Reflective' by Kahneman (2011) and Thaler and Sunstein (2008) respectively.

be contracted out to organizations with professional experience in the art of communication. Whoever leads the process, it is highly desirable that key stakeholders participate actively or are adequately represented during regular formal and informal progress meetings.

It is desirable also that key stakeholders play a central role in communicating key messages. Among stakeholders, there are nearly always a number who are well-respected opinion leaders and who have particular communication skills and opportunities to convey and articulate messages to other stakeholders and the wider public. Such stakeholders should also be encouraged to act as lead communicators with the media and the general public.

Generic activities that are needed to get communication started include the following:

- **Creating an appropriate culture:** Communication will be most effective during a water accounting and auditing process if a culture of open and effective communication is created. Essentially, communication should be inclusive, open and respected by everyone involved.
- **Review earlier or ongoing communication campaigns:** Communication is a standard component of most government, international agency or NGO projects and programmes. Hence, there are often lessons to be learned from these projects and programmes.
- **Choice of language:** Selecting an appropriate language, or a mix of languages, may not be a major issue in some countries or specified domains but in others this may be a critical issue.
- **Choice of communication technologies:** Similar to the above, it may be necessary to select communication technologies that do not alienate or exclude certain stakeholder groups or the wider public.
- **Stakeholder analysis:** Segmentation and targeting of stakeholders should be used to identify the stakeholders who have both a high level of interest in water accounting and auditing findings, outputs and recommendations and the power to directly influence policy and practice at different institutional levels.

BOX 6.11
Who is interested?

Don't make the mistake of thinking that just because you have something important to say, people will want to hear you. How you convey information can be just as important as what you have to say. Pre-testing messages, through focus groups or market research, can help fine-tune them. Pre-testing considers variables such as comprehension, attractiveness, acceptance, involvement and inducement to action. A less elaborate test is to ask the question: Why should people care? If you can't answer this easily, in one sentence, you may need to do additional work.

Source: UNDP, 2013

6.3.6 Preparation of a communication strategy: stepwise process

Once 'getting started' activities have been completed, it is possible to move on to the main communication stepwise process. The following is a typical process:

Step 1: Undertake a needs assessment. The main aim of this step is to ensure that the water accounting and auditing communication strategy is based on needs that, in many cases, will evolve over time. This step involves an initial assessment of the communication needs, and objectives, for both internal and external communication. Internal communication will focus mainly on routine sharing and exchanging information, dialogue and joint learning. Whereas the focus of external communication is more likely to be on communicating on a regular basis with and stakeholders who are not engaged with the water accounting and auditing process. Particular attention should be given to stakeholders at different institutional levels who are powerful and have interests that are well aligned with the water accounting and auditing outputs and recommendations.

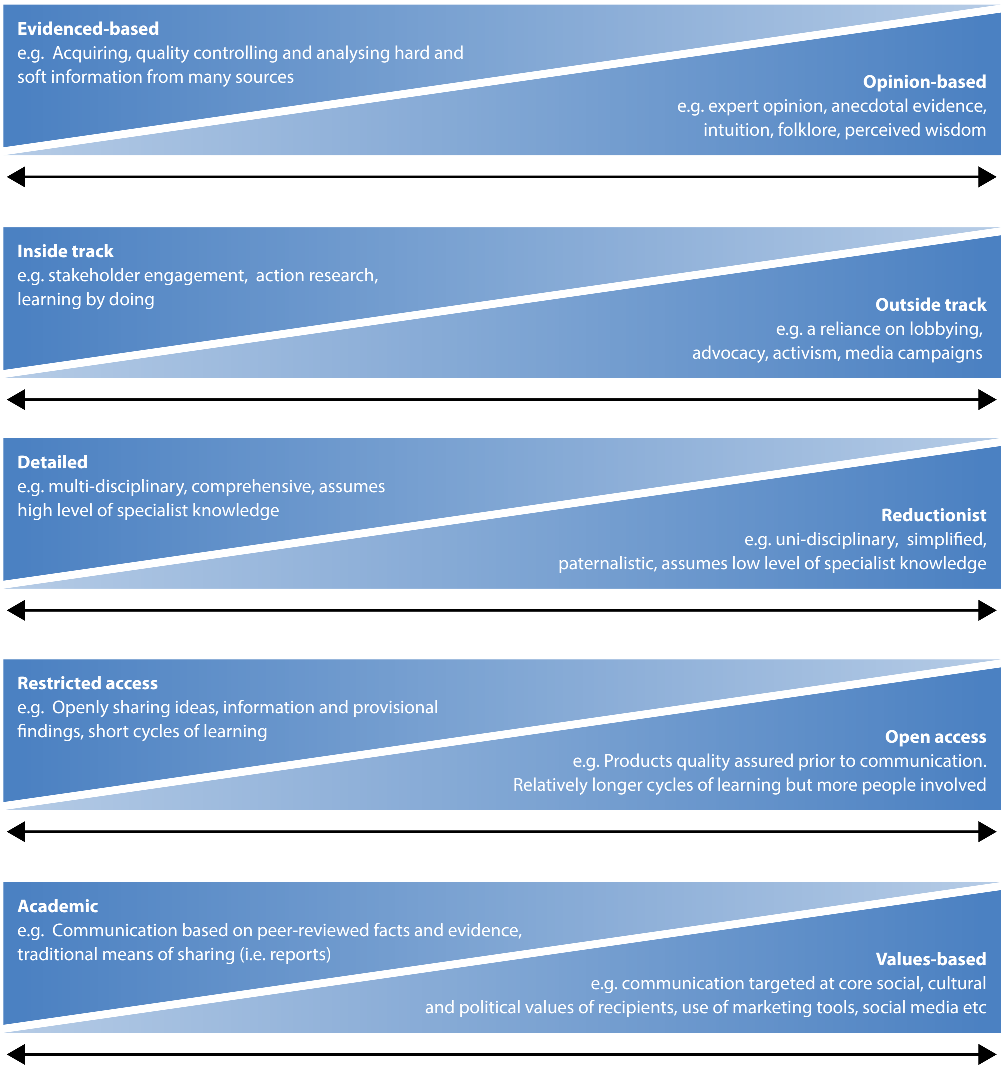
Step 2: Develop a communication strategy. A communications strategy[112] should have short, medium and long-term targets with specific deadlines for achievement (UNDP, 2013). A common mistake in communication work is to underestimate the time and resources required or to try to pack in too many activities. As such, it is advisable to prioritise activities and build in flexibility for changes along the way. If you need to make choices, the first preference should be for activities that combine high impact with low cost. Clear lines of accountability should be agreed that spell out individual responsibilities. This includes determining: Who will manage the strategy? Who will monitor its implementation? What happens if deadlines are missed? Who will handle the media if there is some kind of crisis that requires a rapid response?

It is also necessary to make choices on key elements of the communication strategy, see Figure 6.2. For example:

- **Should inputs to communication products be evidence or opinion based?** As a general rule, it is better if communication products are evidence-based. However, it may be expedient to use opinion-based products when time is limited or when triangulating evidence-based products.
- **Should the communication strategy focus more on inside or outside track communication?** In most cases, a balance needs to be struck. Some stakeholders will be more closely engaged in water accounting and auditing than others and, as result, they will be on the inside track and have a relatively high-level of ownership of outcomes, findings and recommendations. Other stakeholders will be less engaged and hence on the outside track. As a result, targeted lobbying, advocacy or similar may be needed to gain or increase their interest and commitment.
- **Should communication products be detailed or reductionist?** Again a balance is usually required. If communication products are overly detailed or specialised, most stakeholders or the wider public will not read them. At the other end of the spectrum, reductionist simplifications will not give stakeholders sufficient information to take an informed view on complicated issues.
- **Should communication be on the basis of restricted or open access?** As far as possible and acceptable, communication in relation to water accounting and auditing should be open and transparent. However, many challenges and opportunities being addressed are highly political. As a result, stakeholder dialogue may be constrained if it takes place in public and under the spotlight of a potentially hostile media. Similarly ill-timed sharing of provisional findings and recommendations may not be helpful because a lot of time and nervous energy could be wasted justifying or defending provisional findings or recommendations

[112] For more detailed information on developing a communication strategy, please see guides that are freely available. For example: http://web.undp.org/comtoolkit/why-communicate/docs/Tools/CommunicationsToolkitAGuidetoNavigatingCommunicationsfortheNonprofitWorld.pdf or http://web.undp.org/comtoolkit/why-communicate/docs/Tools/10stepsforDesigningaCommunicationsStrategyforBehaviouralImpact.pdf

FIGURE 6.2
Some important choices for communication strategy



that have not been fully thought through.

- **Should communication be academic or values based?** In most cases, it is a case of segmenting and knowing the target audiences of a communication campaign. In some cases, it may be important that the emphasis is on verifiable facts and evidence. In others, effective communication may be more likely if the communication is targeted at the social, cultural or political values of recipients.

Step 3: Implement the communication strategy. Communicating with and between stakeholders, organizations tasked with water accounting and auditing, and the wider public is not a public relations exercise. Particularly in all aspects of stakeholder engagement, those responsible for implementing the communication strategy should be impartial, neutral and act as facilitators. At one level, implementation of the strategy should ensure that: 1) Information is made accessible in formats that are useful to whoever may need it; 2) Opportunities are provided for formal and informal dialogue either face to face or using reliable technologies; and 3) Opportunities are provided for stakeholders or the wider public to contest information or findings, recommendations and other outputs from the water accounting and auditing process. At another level, communication also involves creating space, for discussion and debate around what needs to be done to solve problems, improve delivery of water services, improve water security or similar.

There are a number of principles that should be followed when implementing a water accounting and auditing communication strategy. These include:

- **Building trust among stakeholders, organizations tasked with the water accounting and auditing:** Trained facilitators can use their experience to recognize concerns, scepticism and doubts. Ignoring or downplaying these signals is likely to reduce levels of trust amongst all concerned. In both formal and informal meetings, those tasked with water accounting and auditing should openly admit when evidence is methodologically weak, mixed or missing.
- **Be iterative and consultative:** Water accounting and auditing should inform the communication process and resulting stakeholder dialogue and debate should inform and, if appropriate, prompt additional cycles of water accounting and auditing.
- **Identify and discuss areas of uncertainty:** In addition to maximizing the flow of information and interactions between all involved in water accounting and auditing, discussion and debate should take place on sources of uncertainty linked to how data were gathered, how they were analysed and how results were interpreted. The scale of uncertainty should be presented probabilistically or in the form of influence diagrams. Rather than undermine trust, this should help demonstrate that the water accounting and auditing process is open and transparent.
- **Seek to frame the debate:** Psychological experiments have shown that the framing of questions and debates can have a major influence on the level of engagement of stakeholders and others. In addition, people can and often do intuitively substitute an esoteric or obscure question with one that is easier to answer (e.g. Kahneman, 2011). The implication is that it is usually more constructive to frame questions or debates around immediate issues in ways that are directly-linked to specific reform initiatives or strategic objectives;
- **Act macro but talk micro:** Experts like to think and talk macro (CommGAP, 2009b). Experts also have a fascination for facts and evidence and a tendency to dominate discussions. But the general public tend not think like that. The general public think micro i.e. ‘What has this issue got to do with me? How does this affect me? Will my life or the lives of my family improve as a result of efforts to address this issue?’ Hence, communication around a reform or strategic objective must have a disciplined micro focus or public support may not be won over (CommGAP, 2009b);
- **Address the biggest fears and concerns of the public:** Don’t just focus on

BOX 6.12
Concise messages

Given the amount of information circulating today, clear and concise messages are needed, for example, to grab the attention of a busy policy maker or rouse the interest of a village official. These messages don’t have to explain all the details—they are designed to present a compelling fact or strike an emotional chord that convinces people to find out more themselves. They should also have a ‘hook’ related to:

- What’s different?
- What’s new?
- What’s gone wrong?
- What’s controversial?
- What’s of general interest?

Source: UNDP, 2013

> BOX 6.13
> **Hydro-politics**
>
> Because water is an essential good, political risk is almost unavoidable when governments pursue unpopular measures, such as attempting to manage or regulate demand for water. It is notable also that politicians also use water as a political tool during campaigns often making promises that are hard to deliver.
>
> *Source: Chaman et al., 2012*

the positive aspects of water accounting and auditing recommendations. The idea of communication is not just to do a 'selling job', but to treat stakeholders and the wider public as adults. Honesty regarding potential externalities will engender trust and credibility. If there is a possibility some citizens or social groups will lose out as a consequence of certain actions, frank and open debates should be organised to address and identify solutions (e.g. compensation arrangements).

- **Talk about issues not politics:** When communicating findings, outputs or recommendations from water accounting or auditing, ideally the focus of communication should rise above petty partisan politics and focus on issues that are demonstrably of public interest or that touch on the social and cultural values of some or all stakeholders.
- **Quality assurance and timeliness:** Communication around water accounting and water auditing should give attention to double-checking or triangulating facts and figures and sharing outputs on schedule. In addition to being unprofessional, communication of outputs that have not been quality assured creates a bad impression.
- **Build coalitions with journalists and other communication programmes:** Communication and particular advocacy is often most effective when carried out in alliances, coalitions and networks (Jones, 2011).

Step 4: Evaluate the impacts and effectiveness of the communication strategy[113]. Evaluation and assessment should be built into the communication strategy. The aim being to: 1) Keep a track progress and performance; and 2) Identify quickly procedures or activities that are underperforming. Some common forms of evaluating communication Include:

- processing documentation;
- writing online questionnaires;
- attending multi-stakeholder platform meetings, workshops and other events;
- translating recommendations into policy or practice.

6.3.7 Communication myths and misconceptions

There are quite a number of myths and misconceptions relating to communication. Some of these have been listed and described in Table 6.2.

[113] More detailed information on communication evaluation and assessment can be found on the internet e.g. http://web.undp.org/evaluation/documents/HandBook/ME-HandBook.pdf or http://www.fao.org/docrep/014/i2195e/i2195e.pdf

TABLE 6.2
Communication myths and misconceptions

Myth	Reality
Any communication is good communication	We are bombarded with communication that is poor. Think of the last time you struggled to stay awake during a speech, gave up trying to decipher a policy paper or had a misunderstanding with a friend. The most successful communications initiatives craft compelling messages for people identified as willing to hear and respond to them
Human beings are rational.	Development communications at large too often makes the mistake of assuming that people will respond primarily to technical information. While highly complex and detailed communications may be appropriate in some circumstances, there are many situations where you will reach people—even highly intellectual people—through their hearts and their emotions, not their heads. Private sector advertising has long been aware of this 'secret', which is why an ad for a new car will generally not explain all the wonderful technical aspects of the engine, but will make people feel prosperous, happy, safe and fulfilled if they drive it
Communications is too expensive and doesn't add value	Public and private sector organizations have proven the value of communicating well. However, poorly planned communications wastes resources and has no impact
Telling people about how awful a situation is will compel them to take action.	People do respond to the suffering of others. But messages that convey too much of a sense of fear and horror, especially about big problems such as poverty, can lead to feelings of apathy. Problems begin to seem so huge they cannot be solved anyway. Research also shows that people have problems imagining the consequences of issues that appear to be far off—such as climate change—because human beings are not programmed to respond to threats that appear too vague or unconnected to their immediate daily lives. For these reasons, effective advocacy often stresses positive messages, and gives people a concrete sense of what they can do to take action
Developmental issues are too complex	No issue is too complex. Depending on which audience you are trying to reach Complicated theories or situations may need to have their core messages distilled,. This may require extra effort or creativity, or thinking outside the box. But it can be done.

Source: UNDP, 2003; UNEP, 2005; FAO, 2011b; and UNDP, 2013

6.4 TIPS AND TRICKS

Practical lessons learned from designing and implementing strategies to communicate the results of water accounting and auditing include:

- Clear, simple and directed communication is more effective than bombarding people with a lot of facts and evidence.
- Don't try to tell people everything at once. Carefully select what information you wish to convey at different times.
- Use segmentation/targeting to ensure that people or organizations receive information that people or organizations need or that is likely to be of most interest to them.
- Don't exaggerate facts and make sure your facts are correct. Confused messages cloud communication and undermine your integrity.
- Listening is critical element of effective communication.

REFERENCES

Allen,R.G., Pereira,L.S, Raes, D. & Smith, M. 1998. Crop evapotranspiration – Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. (Available at: http://www.fao.org/docrep/X0490E/X0490E00.htm). Accessed 18 April 2016.

Alfredson, T. & Cungu, A. 2008. Negotiation theory and practice: A review of the literature. FAO Policy Learning Programme. (Available at: http://www.fao.org/docs/up/easypol/550/4-5_negotiation_background_paper_179en.pdf).

Anderson, M.C. Allen, R.G, Morse, A. & Kustas, P. 2012. Use of Landsat thermal imagery in monitoring evapotranspiration and managing water resources. Remote Sensing of Environment Volume 122. (Available at: http://www.sciencedirect.com/science/journal/00344257/122/supp/C). Accessed 18 April 2016.

Andrews, M. 2013. The limits of institution reform in development. UK, Cambridge University Press.

Ames, D.P., Horsburgh, J.S. Yang Cao, Kadlec, J., Whiteaker, T. & Valentine, D. 2012. HydroDesktop: Web services-based software for hydrologic data discovery, download, visualization, and analysis. *Environmental Modelling & Software* 37.

Arnell, N., & Chunzhen L. 2001. Hydrology and Water Resources. In IPCC Report: Climate Change 2001: *Impacts, Adaptation, and Vulnerability.* (Available at: http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=159). Accessed 18 April 2016.

Barnes, J. 2009. Okavango River Basin Transboundary Diagnostic Analysis: socioeconomic assessment. OKACOM-EPSMO

Bastiaanssen, W.G.M. 2009. Water accounts: de nieuwe generatie waterbeheercontroleurs. Intreerede Technische University of Delft. (in Dutch)

Batchelor, J. 2013. Using GIS and SWAT analysis to assess water scarcity and WASH services levels in rural Andhra Pradesh. IRC International Water and Sanitation Centre, The Hague, The Netherlands. (Available at www.ircwash.org).

Baties, S.S. 2008. Wicked Problems and applied economics. *Amer. J. Agr. Econ.* 90 No. **5. (Available at: http://www.oecd.org/agriculture/agricultural-policies/43926484.pdf).**

Bekchanov, M., Sood, A. & Jeuland, M. 2015. Review of hydro-economic models to address river basin management problems: structure, applications and research gaps. Colombo, Sri Lanka: International Water Management Institute (IWMI). 60p. *IWMI Working Paper 167.* doi: 10.5337/2015.218.

Bester, A. 2012. Results-based management in the United Nations Development System: Progress and Challenges. UNDESA. (Available at: http://www.un.org/esa/coordination/pdf/rbm_report_10_july.pdf).

Beven, K. 2009. *Environmental modelling: an uncertain future.* UK, Routledge.

Beven, K. 2012. *Rainfall-runoff modelling: The primer.* UK, Wiley-Blackwell.

Beven, K. 2015. Facets of uncertainty: epistemic uncertainty, non-stationarity, likelihood, and communication. *Hydrological Sciences Journal. (* Available at: http://www.tandfonline.com/doi/pdf/10.1080/02626667.2015.1031761).

Beven, K., Buytaert, W. & Smith, L. A. 2012. On virtual observatories and modelled realities (or why discharge must be treated as a virtual variable). *Hydrol. Process.* 26: 1905–1908.doi: 10.1002/hyp.9261. (Available at: http://onlinelibrary.wiley.com/doi/10.1002/hyp.9261/full).

Beven, K. & Binley, A. 2014. GLUE: 20 years on. *Hydrol. Process. 28.* (Available at: http://onlinelibrary.wiley.com/doi/10.1002/hyp.10082/full).

Blanco-Gutiérrez, I., Varela-Ortega. C. & Purkey. D.R. 2013. Integrated assessment of policy interventions for promoting sustainable irrigation in semi-arid environments: A hydro-economic modeling approach. *Journal of Environmental Management,* 128 144e160.

Bloschl, G. & Sivapalan, M. 1995. Scale issues in hydrological modelling: A review. *Hydrological Processes,* Vol 9, 251-290.

Bos, M.G., Burton, M.A. & Molden, D.J. 2005. Irrigation and drainage performance assessment. Practical Guidelines. Wallingford, UK, Centre for Agriculture and Biosciences International (CABI).

Buffardi, A., Hearn, S., Pasanen,T., Price, C. & Ball, L. 2015. Ten things to know about evaluation. London, Overseas Development Institute (ODI). (Available at: http://www.odi.org/publications/9105-10-things-know-about-evaluation).

Burt. C. M. *Irrigation water balance fundamentals.* 1999. Conference on benchmarking irrigation system performance using water measurement and water balances. San Luis Obispo, CA, USA, Interstate Technology and Research Council (ITRC). (Available at http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1066&context=bae_fac). Accessed 18 April 2016).

Butterworth, J., McIntyre, P. & da Silva Wells, C. 2011. *SWITCH in the city: putting urban water management to the test*. The Hague, The Netherlands, IRC International Water and Sanitation Centre. (Available at: http://www.switchurbanwater.eu/outputs/pdfs/SWITCH_in_the_City.pdf). Accessed 18 April 2016.

Buytaert, W., Baez, S., Bustamante, M. & Dewulf, A. 2012. Web-based environmental simulation: bridging the gap between scientific modeling and decision-making. *Environ. Sci. Technol.* 2012, 46, 1971–1976.

Calejo, M.J., Lamaddalena, N., Teixeira, J.L., Pereira, L.S. 2008. Performance analysis of pressurized irrigation systems operating on-demand using flow driven simulation models. *Agric. Water Manage.* 95 (2), 154–162.

Chaman, K., Miller, T. & Mitchel, P. 2012. *Communication for water sector reform: Obstacles and opportunities.* Washington, DC, USA, World Bank. (Available at: http://siteresources.worldbank.org/EXTGOVACC/Resources/Tech_note_1_water_web_12-17-12.pdf). Accessed 18 April 2016.

Care. 2005. Tips for collecting, reviewing, and analyzing secondary data. (Available at: http://pqdl.care.org/Practice/DME%20-%20Tips%20for%20Collecting,%20Reviewing%20and%20Analyzing%20Secondary%20Data.pdf). Accessed 18 April 2016.

Clemmens, A.J. 2006. Improving irrigated agriculture performance through an understanding of the water delivery process. Irrig. Drain. 55 (3), 223–234

Clemmens, A.J. & Molden, D.J. 2007. Water uses and productivity of irrigation systems. Irrig. Sci. 25, 247–261.

CommGAP. 2009a. *The Political Economy of Reform: Moving from Analysis to Action. A Global Learning Event,* CommGAP, World Bank, Washington, DC, USA. (Available at: http://siteresources.worldbank.org/EXTGOVACC/Resources/PoliticalEconomyAnalysistoActionFinalReport.pdf). Accessed 18 April 2016).

CommGAP. 2009b. *Political economy analysis to action: political communication approaches and techniques,* CommGAP, Washington, DC, World Bank. (Available at: http://www.gsdrc.org/docs/open/DOC106.pdf). Accessed 18 April 2016.

Copestake, J. & Williams, R. 2012. *The evolving art of political economy analysis: Unlocking its practical potential through a more interactive approach.* (Available at: http://www.opml.co.uk/sites/opml/files/OPM_DF_political%20economy%20analysis.pdf). Accessed 18 April 2016.

Cowling, P., DeValue,K. & Rosenbaum,K. 2014. Assessing forest governance: A practical guide to data collection, analysis and use. Washington DC and Rome, PROFOR and FAO. (Available at: http://www.fao.org/3/a-i3918e.pdf). Accessed 18 April 2016.

Croke, B.F.W., Blakers, R.S., El Sawah, S., Fu, B., Guillaume, J.H.A. Kelly, R.A., Ross, A. Ticehurst, J., Barhel, R. & Jakeman, A.J. 2014. Marrying hydrological modelling and integrated assessment for the needs of water resource management Evolving Water Resources Systems: Understanding, Predicting and Managing Water–Society Interactions Proceedings of ICWRS 2014, Bologna, Italy, June 2014 (IAHS Publ. 364).

Crompton, T. 2010. Common Cause: The Case for Working with our Cultural Values. WWF, Oxfam, Friends of the Earth, CPRE, Climate Outreach Information Network. (Available at: http://assets.wwf.org.uk/downloads/common_cause_report.pdf). Accessed 3 May 2016)

Curtis A, and Wood R. 2004. Geological prior information: informing science and engineering. Curtis A, and Wood R, editors. Bath, UK: Geological Society, 2004. Dalolu, I., Nassauer, J.I., Riolo, R. & Scavia.D. 2014. An integrated social and ecological modeling framework—impacts of agricultural conservation practices on water quality. Ecology and Society, 19(3): (Available at: 12. http://dx.doi.org/10.5751/ES-06597-190312). Accessed 21 April 2016.

da Silva, M.G., de Oliveira de Aguiar Netto, A., de Jesus Neves, R.J., do Vasco, A.N., Almeida, C. & Faccioli, G.G. 2015. Sensitivity analysis and calibration of hydrological modeling of the watershed northeast Brazil. Journal of Environmental Protection, 6, 837-850. (Available at: http://dx.doi.org/10.4236/jep.2015.68076). Accessed 18 April 2016.

Davis, G. 2002. *Scenarios as a tool for the 21st Century.* Probing the Future Conference, Strathclyde University, July 12, 2002. Shell International Limited. (Available at: http://www.pik-potsdam.de/news/public-events/archiv/alter-net/former-ss/2006/programme/31-08.2006/leemans/literature/davis_how_does_shell_do_scenarios.pdf). Accessed 18 April 2016.

de Waal, A. 2015. *Policy to research to policy in difficult places.* Washington, DC, World Bank. People, Spaces, Deliberation. (Available at: http://blogs.worldbank.org/publicsphere/policy-research-policy-difficult-places). Accessed 18 April 2016.

DFID. 2007. Refining the analytical framework to understand the politics of the places where we work. (http://www.gsdrc.org/docs/open/DOC104.pdf). Accessed 21 April 2016.

DFID. 2009. *Eliminating world poverty: Building our common future.* London, Department for International Development. (Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/229029/7656.pdf). Accessed 18 April 2016.

Dingman, S. L. 2002. *Physical hydrology, Second Edition,* USA, Prentice Hall, 646 p.

Dore, J., Robinson, J. & Smith, M. (Eds). 2010. Negotiate – Reaching agreements over water. Gland, Switzerland, IUCN. (Available at: http://data.iucn.org/dbtw-wpd/edocs/2010-006.pdf). Accessed 18 April 2016.

Duncan, A. & G. Williams. 2010. Making development assistance more effective by using political economy analysis: what has been done and what have we learned? Development Policy Review. Volume 30, Issue 2, pp. 133–148.

Edwards, V.M. & Stein, N.A. 1998. Developing an analytical framework for multiple-use commons. Journal of Theoretical Politics, 10(3), 347-83.

EPA. 2008. Handbook for developing watershed plans to restore and protect our waters. United States, Environmental Protection Agency. (Web site: http://water.epa.gov/polwaste/nps/upload/2008_04_18_NPS_watershed_handbook_handbook-2.pdf). Accessed 18 April 2016.

Eppstein, M.J., Horbar, J.D., Buzas, J.S. & Kauffman, S.A. 2012. Searching the clinical fitness landscape. PLoSONE 7(11): e49901. (Available at: doi:10.1371/journal.pone.0049901). Accessed 18 April 2016.

European Union (EU). 2008. Analysing and Addressing Governance in Sector operations. Tools and Methods Series. Reference Document No. 4.

FAO. 2012b. *Coping with Water Scarcity, the Role of Agriculture. Cubango-Okavango River Basin Water Audit.* Synthesis report. Rome. [Available at http://www.fao.org/docrep/019/i3743e/i3743e.pdf]

FAO. 2013. *Coping with Water Scarcity, the Role of Agriculture. Developing a Water Audit for Awash River Basin*. Synthesis report. Addis Ababa, Ethiopia. [Available at http://www.fao.org/nr/water/docs/awash/AwashSynthesisReport.pdf]

FAO. 2002. *Crops and drops: Making the best use of water for agriculture.* Rome, FAO.

FAO. 2011a. *The state of the word's land and water resources for food and agriculture: Managing systems at risk* (SOLAW). Rome, FAO; London, Earthscan. (Available at: http://www.fao.org/docrep/017/i1688e/i1688e.pdf). Accessed 18 April 2016.

FAO. 2011b. *Food security communications toolkit.* (Available at: http://www.fao.org/docrep/014/i2195e/i2195e.pdf). Accessed 18 April 2016.

FAO. 2012. Coping with water scarcity: An action framework for agriculture and food security. *FAO Water Reports 38.* (Available at: http://www.fao.org/docrep/016/i3015e/i3015e.pdf). Accessed 18 April 2016.

Foster, S., Perry, C., Hirata, R. & Garduno, H., 2009. *Groundwater resource accounting: critical for effective management in a changing world.* GW-MATE Briefing note 16. Washington, DC. World Bank.

Foster, S.S.D. & Perry, C.J. 2010. Improving groundwater resource accounting in irrigated areas: a prerequisite for promoting sustainable use, Hydrogeol. J., 18, 291–294, 2010.

Forresti, M. & Wild, L. 2014. *Governance target and indicators for post 2015.* (Available at: http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8789.pdf). Accessed 18 April 2016.

Frederiksen, H.D. & Allen, R.G. 2011. A common basis for analysis, evaluation and comparison of off stream water uses. *Water International*, 36, 266–282.

Frederiksen, H.D., Allen, R.G., Burt, C.M. & Perry, C. 2012. Responses to Glieck et al. 2011, which was itself a response to Frederiksen and Allen. 2011. [Correspondence]. *Water International,* 37, 183–197.

Fritz, V., Levy, B. & Ort, R. 2014. Problem-driven political economy analysis: The World Bank's experience. Directions in Development. Washington, DC, World Bank. (Available at: doi:10.1596/978-1-4648-0121-1. License: Creative Commons Attribution CC BY 3.0). Accessed 18 April 2016.

Giddens, A .1979. *Central problems in social theory,* London, Macmillan.

Gleick, P.H., Christian-Smith, J. & Cooley, H. 2011. Water use efficiency and productivity rethinking the basin approach. W*ater International,* 36, 784–798.

Green, C. 2011. Mapping the field: the landscape of governance. SWITCH Project. (Available at: http://www.switchurbanwater.eu/outputs/pdfs/W6-1_GEN_RPT_D6.1.1b_Mapping_Landscapes_of_Governance.pdf). Accessed 18 April 2016.

Green, D. 2013. What is a theory of change and how do we use it? (Available at: http://blogs.worldbank.org/publicsphere/what-theory-change-and-how-do-we-use-it). Accessed 18 April 2016.

Grindle, M. 2004. Good enough governance: poverty reduction and reform in developing countries, *Governance: An International Journal of Policy, Administration and Institutions,* 17: 525-48. . (Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.0952-1895.2004.00256.x/abstract). Accessed 18 April 2016.

Grindle, M. 2007. Good enough governance revisited. *Development Policy Review,* 2007, 25 (5): 553-574. (Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1467-7679.2007.00385.x/abstract). Accessed 18 April 2016.

GWP. 2000. *Towards water security: a framework for action,* Stockholm, Sweden, Global Water Partnership. (Web site: www.gwpforum.org).

GWP. 2013. The role of decision support systems and models in integrated river basin management. Technical Focus Paper. (Available at: http://www.gwptoolbox.org/images/stories/gwplibrary/technical_focus/gwp%20tfp%20dss_final.pdf). Accessed 18 April 2016.

Harou, J.J., Pulido-Velazquez, M., Rosenberg, D.E., Medellín-Azuara, J. & Lund and Howitt,J.R. 2009. Hydro-economic models: Concepts, design, applications, and future prospects. *Journal of Hydrology,* 375 (2009) 627–643

Harris, D. 2013. Applied political economy analysis. *A problem-driven framework.* (Available at: http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8334.pdf). Accessed 18 April 2016.

Harris, D., Jones, L. & Kooy, M. 2011. *Analysing the governance and political economy of water and sanitation service delivery*. ODI Working Paper 334. London, Overseas Development Institute. (Available at: http://www. odi.org.uk/resources/docs/7243.pdf). Accessed 18 April 2016.

Haugaard, M. (Ed). 2002. *Power: a reader,* Manchester, UK, Manchester University Press.

Horsburgh, J.S., Tarbotton, D.G., Piasecki, M., Maidment, D., Zaslavsky, I., Valentine, D. & Whitenack, T. 2009. An integrated system for publishing environmental observations data. *Environmental Modelling & Software,* 24 879-888.

Hovland, I. 2005. *Successful communication: a toolkit for researchers and civil society organizations*. UK, Overseas Development Institute. Available at: http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/192.pdf). Accessed 18 April 2016.

Howes, S. & Wyrwoll, P. 2012. *Asia's wicked environmental problems.* ADBI Working Paper 348. Tokyo, Asian Development Bank Institute.

Hrachowitz, M., Savenije, H.H.G., Blöschl, G., McDonnell, J.J., Sivapalan, M., Pomeroy, J.W., Arheimer, B., Blume, T., Clark, M.P., Ehret, U., Fenicia, F., Freer, J.E., Gelfan, A., Gupta, H.V., Hughes, D.A., Hut, R.W., Montanari, A., Pande, S., Tetzlaff, D., Troch, P.A., Uhlenbrook, S., Wagener, T., Winsemius, H.C., Woods, R.A., Zehe, E. & Cudennec, C. 2013. A decade of predictions in ungauged basins (PUB)—a review. *Hydrological Sciences Journal,* 58 (6), 1198–1255.

Hsiao, T.C., Steduto, P. & Fereres, E. 2007. A systematic and quantitative approach to improve water use efficiency in agriculture. *Irrig. Sci.* 25, 209–231.

Innocent, T. 2013. *Making sense out of uncertainty*. London School of Economics. (Available at: http://blogs.lse.ac.uk/impactofsocialsciences/2013/07/22/making-sense-of-uncertainty-sense-about-science/). Accessed 18 April 2016.

Islam S. L. Susskind L. 2012. Water Diplomacy: A negotiated approach to managing complex water networks. New York, Routledge.

IUFRO. 2007. How do forests influence water? IUFRO Fact Sheet No 2. (Available at: http://www.iufro.org/download/file/4384/4475/fact-sheet-07-water_pdf). Accessed 18 April 2016.

Jakeman, A.J. 2014. M*arrying hydrological modelling and integrated assessment for the needs of water resource management. Evolving Water Resources Systems: Understanding, Predicting and Managing Water–Society Interactions.* Proceedings of ICWRS2014, Bologna, Italy, June 2014 (IAHS Publ. 364).

Jakeman, A.J., Letcher, R.A. & Norton, J.P. 2006. Ten iterative steps in development and evaluation of environmental models. *Environmental Modelling & Software,* Volume 21, Issue 5, 602-614.

Jakeman, A.J., Merritt, W., Fu, B., Kelly, R., Pollino, C., Ticehurst, J. El Sawah, S.E., Guillaume, J.H.A. 2013. *Decision support systems: experiences, lessons and recommendations.* Twenty-second NSW Coastal Conference, 12-15 November 2013, Glasshouse, Port Macquarie, NSW.

James, A.J., Kumar, M.D, Batchelor, J.R., Batchelor, C.H., Bassi, N., Choudhary, J. Gandhi, D., Syme, G., Milne, G. & Kumar, P. 2015. Catchment Assessment and Planning for Watershed Management. Washington, DC, The World Bank.

Johnson, K. A., G. Dana, N. R. Jordan, K. J. Draeger, A. Kapuscinski, L. K. Schmitt Olabisi & P. B. Reich. 2012. Using participatory scenarios to stimulate social learning for collaborative sustainable development. Ecology and Society 17(2): 9. (Available at: http://dx.doi.org/10.5751/ES-04780-170209). Accessed 18 April 2016.

Jones, H. 2011. *A guide to monitoring and evaluating policy influence*. Background Note, Overseas Development Note. (Available at: http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6453.pdf). Accessed 18 April 2016.

Juston, J.M., Kauffeldt, A., Quesada Montano, B., Seibert, J., Beven, K. J. & Westerberg, I.K. 2013. Smiling in the rain: seven reasons to be positive about uncertainty in hydrological modelling, Hydrol. Process., 27, 1117–1122, 2013.

Kahan,D. 2008. Managing risk in farming. Rome, FAO. (Available at: http://www.fao.org/uploads/media/3-ManagingRiskInternLores.pdf). Accessed 18 April 2016.

Kahneman, D. 2011. *Thinking, fast and slow.* Penguin Books.

Karimi, P., Bastiaanssen, W.G.M. & Molden, D. 2013a. *Water accounting (WA+) – a water accounting procedure for complex river basins based on satellite measurements.*

Karimi, P., Bastiaanssen, W.G.M., Molden, D. & Cheema, M.J.M. 2013b. Basin-wide water accounting using remote-sensing data: the case of transboundary Indus Basin.

Karimi, P., Bastiaanssen, W.G.M, A. Sood, A., Hoogeveen,J., Peiser, L., Bastidas-Obando, E. & Dost, R.J. 2015. Spatial evapotranspiration, rainfall and land use data in water accounting – Part 2: Reliability of water accounting results for policy decisions in the Awash Basin. Hydrol. Earth Syst. Sci., 19, 533–550, 2015.

Keller, A. & J. Keller. 1995. *Effective efficiency: A water use concept for allocating freshwater resources*. Water Resources and Irrigation Division Discussion Paper 22. Arlington, VA, USA, Winrock International.

Keller, A., Keller, J. & Seckler, D. 1996. *Integrated water resource systems: Theory and policy implications.* Research Report 3. Colombo, Sri Lanka, International Irrigation Management Institute.

Knox, J.W., Morris, J., Weatherhead, E.K. & Turner, A.P. 2000. Mapping the financial benefits of sprinkler irrigation and potential financial impacts of restrictions on abstractions: a case-study in Anglian Region. J. *Environ. Manage.* 58, 45–59.

Knox, J.W., Kay, M.G. & Weatherhead, E.K. 2012. Water regulation, crop production, and agricultural water management — Understanding farmer perspectives on irrigation efficiency. *Agricultural Water Management* 108 (2012) 3– 8.

Kooy, M. & Harris, D. 2012. *Political economy analysis for water, sanitation and hygiene (WASH) service delivery.* Overseas Development Institute. (Available at: http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/7797.pdf). Accessed 18 April 2016.

Lakoff, G. 2009. The political mind: A cognitive scientist's guide to your brain and its politics, London, Penguin.

Laniak, G.F, Gabriel Olchin, G., Goodall, J., Voinov, A., Hill, M., Glynn, P., Whelan, G., Geller, G., Quinn, N., Blind, M., Peckham, S., Reaney, S., Gaber, N., Kennedy, R., Hughes, A. 2013. Integrated environmental modeling: A vision and roadmap for the future. *Environmental Modelling & Software,* 39, 3-23.

Lankford, B.A. 2012. Fictions, fractions, factorials and fractures; on the framing of irrigation efficiency. *Agricultural Water Management,* 108 (2012) 27– 38.

Lankford, B.A. 2013. *Resource efficiency complexity and the commons: the paracommons and paradoxes of natural resource losses, wastes and wastages.* UK, Routledge.

Lovallo, D. & Sibony, O. 2010. The case of behavioural strategy. *McKinsey Quarterly,* March 2010.

Macal, C.M. & North, M.J. 2006. Introduction to agent-based modeling and simulation. Decision & Information Sciences Division, Argonne National Laboratory, Argonne, IL 60439 USA. (Available at: http://www.mcs.anl.gov/~leyffer/listn/slides-06/MacalNorth.pdf). Accessed 3 May 2016.

Mcloughlin, C. 2014. Topic Guide on Political Economy Analysis. (Updated guide, first published in 2009). http://www.gsdrc.org/wp-content/uploads/2015/07/PEA.pdf

Merrey, D. & Cook, S. 2012. Fostering institutional creativity at multiple levels: towards facilitated institutional bricolage. *Water Alternatives, 5*(1): 1-19.

Merriam, J.L., Styles, S.W. & Freeman, B.J. 2007. Flexible irrigation systems: concept, design, and application. J. *Irrig. Drain. Eng.* 133 (1), 2–11.

Molden, D., Murray-Rust, H., Sakthivadivel, R. & Makin, I. 2003. A water-productivity framework for understanding and action. In: Kijne, J.W., Barker, R., Molden, D. (Eds). *Water productivity in agriculture: Limits and opportunities for improvement.* Wallingford, IWMI & CABI Publishing, pp. 1–18.

Molden, D. (Ed.). 2007. *Water for food, water for life: A comprehensive assessment of water management in agriculture.* London, Earthscan & Colombo, International Water management Institute.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M.A. & Kijne, J. 2010. Improving agricultural water productivity: between optimism and caution. Agric. Water Manage. 97, 528–535.

Monbiot,G. 2010. *The values of everything.* (Available at: http://www.monbiot.com/2010/10/11/the-values-of-everything/). Accessed 18 April 2016.

Moriarty, P.B. Batchelor, C.H. Laban, P. & Fahmy, H. 2007. The EMPOWERS approach to water governance: Background and key concepts. Euro-Med Participatory Water Resources Scenario Project. Published by: Jordan, Inter-Islamic Network on Water Resources Development and Management (INWRDAM) (Available at: http://water.cedare.int/files15%5CFile2841.pdf). Accessed 18 April 2016.

Moriarty, P.B., Batchelor, C.H., Laban, P. & Fahmy, H. 2010. Developing a practical approach to 'light IWRM' in the Middle East. *Water Alternatives* 3(1): 122-136

Moriarty, P., Smits, S., Butterworth, J. & Franceys, R. 2013. Trends in rural water supply: Towards a service delivery approach. *Water Alternatives* 6(3): 329-349

NEWATER. 2009. Uncertainty in adaptive water management: concepts and guidelines. Germany, Osnabruck University. (Available at: http://www.newater.uni-osnabrueck.de/index.php?pid=1045). Accessed 18 April 2016.

OECD. 2009. *Donor approaches to governance assessments: Guiding principles for enhanced impact, usage and harmonisation.* Paris, Organization for Economic Cooperation and Development.

Pahl-Wostl, C. 2009. A conceptual framework for analysising adaptive capacity amd multi-level learning processes in resource governance regimes. Global *Environmental Change,* 19, 354-365.

Pappenberger, F. & Beven, K. J. 2006. Ignorance is bliss: or seven reasons not to use uncertainty analysis, *Water Resour.* Res., 42, W05302 doi:10.1029/2005WR004820.

Pereira, L.S., Oweis, T. & Zairi, A. 2002. Irrigation management under water scarcity. Agric. *Water Manage*. 57, 175–206.

Pereira, L.S., Cordery, I. & Iacovides, I. 2012. Improved indicators of water use performance and productivity for sustainable water conservation and saving. Agricultural *Water Management,* 108, 39– 51

Perry, C. 2007. Efficient irrigation; inefficient communication; flawed recommendations. *Irrigation and Drainage*, 56: 367–78.

Perry, C. 2012. Accounting for water: stocks, flows, and values. In: UNU-IHDP & UNEP (2012). *Inclusive Wealth Report 2012. Measuring progress toward sustainability*. Cambridge, Cambridge University Press.

Perry, C., Steduto, P., Allen, R.G. & Burt, C.M. 2009. Increasing productivity in irrigated agriculture: agronomic constraints and hydrological realities. Agric. *Water Manage*. 96 (11), 1517–1524.

Pollino, C.A. & Henderson, C. 2010. Bayesian networks: *A guide for their application in natural resource management and policy.* Commonwealth Scientific and Industrial Research Organisation (CSIRO). (Available at: http://www.utas.edu.au/__data/assets/pdf_file/0009/588474/TR_14_BNs_a_resource_guide.pdf). Accessed 18 April 2016.

Ratcliffe, J. S. 2000. Scenario building: A suitable method for strategic construction industry planning? Futures Academy, Dublin Institute of Technology. (Available at: http://arrow.dit.ie/futuresacart/?utm_source=arrow.dit.ie%2Ffuturesacart%2F12&utm_medium=PDF&utm_campaign=PDFCoverPages). Accessed 18 April 2016.

Rao, S. 2014. *Problem-driven iterative approaches and wider governance reform.* (Available at: http://gsdrc.org/docs/open/HDQ1099.pdf). Accessed 18 April 2016.

Renault, D. & Wallander, W.W. 2000. Nutritional water productivity and diets. Agric. *Water Manage.* 45 (3), 275–296.

Rocha Menocal, A. 2014. *Getting real about politics: from thinking politically to working differently.* Overseas Development Institute. (Available at: http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8887.pdf). Accessed 18 April 2016.

Rogers, P. & Hall, A. 2003. *Effective Water Governance. Technical Committee. Background Paper No. 7.* Stockholm, Global Water Partnership (GWP).

Roxburgh, C. 2009. The use and abuse of scenarios. McKinsey Quarterly. McKinsey & Company (Published November 2009) (Available at: http://valor-art.net/Publicacoes/26.pdf). (Accessed 18 April 2016).

Royal Society. 2010. Climate change: *A summary of the science.* UK, The Royal Science. (Available at https://royalsociety.org/topics-policy/publications/2010/climate-change-summary-science/). Accessed 18 April 2016.

Royal Society. 2014. *Climate change evidence and causes. An overview from the Royal Society and the US National Academy of Sciences.* (Available at: https://royalsociety.org/~/media/Royal_Society_Content/policy/projects/climate-evidence-causes/climate-change-evidence-causes.pdf). Accessed 18 April 2016.

RWSN. 2009. *Myths of the rural water supply sector. Rural Water Supply Network, Perspectives No 4.* (Available at: http://www.ircwash.org/sites/default/files/RWSN-2010-Myths.pdf). Accessed 18 April 2016.

Sadegh, M. & Vrugt, J.A. 2013. Bridging the gap between GLUE and formal statistical approaches approximate Bayesian computation. *Hydrol. Earth Syst. Sci.*, 17, 4831–4850, 2013. (Available at: www.hydrol-earth-syst-sci.net/17/4831/2013/ doi:10.5194/hess-17-4831-2013). Accessed 3 May 2016).

Sadegh, M. & Vrugt, J.A. 2014. Approximate Bayesian Computation using Markov Chain Monte Carlo simulation: DREAM(ABC), *Water Resour.* Res., 50. (Available at: doi:10.1002/2014WR015386). Accessed 18 April 2016.

Sapiano, M., Mangion, J. & Batchelor, C.H. 2006. *Malta Water Resources Review.* Rome, FAO. (Available at: ftp://ftp.fao.org/docrep/fao/009/a0994e/a0994e.pdf). Accessed 18 April 2016.

Scott, C.A., Vicuña, S., Blanco-Gutiérrez, I., Meza, F. & Varela-Ortega, C. 2014. Irrigation efficiency and water-policy implications for river basin resilience. *Hydrol. Earth Syst. Sci.*, 18, 1339–1348.

Senay B.G.; Bohms, S.; Singh, R.K.; Gowda, P.H.; Velpuri, N.M.; Alemu, H.; Verdin, J.P. 2013. Operational evapotranspiration mapping using remote sensing and weather datasets: A new parameterization for the SSEB approach. J. *Am. Water Resour. Assoc. 2013, 49, 577–591*.

Sharpley, A., Cochran, M., Daniels, M., Haggard, B., Matlock, M., Riley, T. & Saraswat, D. 2010. *The role of nonpoint source models in watershed management.* Public Policy Centre, University of Arkansas.

Shell International. 2008. Scenarios: *An explorer's guide*. (Available at: http://norren.no/wp-content/uploads/shell-scenarios-explorersguide.pdf). Accessed 18 April 2016.

Shilling, F., Sommarstrom, S., Kattelmann, R., Washburn, B., Florsheim, J. & Henly, R. 2005. *California Watershed Assessment Manual: Volume I.* Prepared for the California Resources Agency and the California Bay-Delta Authority. (Available at: http://cwam.ucdavis.edu). Accessed 18 April 2016.

Shoemaker, L., Dai, T. & Koenig, J. 2005. TMDL *Model Evaluation and Research Needs*. EPA/600/R-05/149.

Silver, N. 2012. The signal and the noise: *The art and science of prediction.* London, Allen and Lane.

Snehalatha M. & Batchelor J. 2013. Skewed and Inequitable access to Rural Water Supply and Sanitation Services. *In Sustainable water and sanitation services : the life-cycle approach to planning and management* / Livelihoods and Natural Resources Management Institute, IRC International Water and Sanitation Centre, Centre for Economic and Social Studies, and Watershed Support Services and Activities Network. ISBN: 978-0-415-82818-5

Speed, R., Li Y., Le Quesne, T., Pegram, G. & Zhiwei, Z. 2013. Basin water allocation planning. Principles, procedures and approaches for basin allocation planning, Paris, UNESCO.

Steduto, P. 1996. Water use efficiency. In: Pereira, L.S., Feddes, R., Gilley, J.R., Lesaffre, B. (Eds.). *Sustainability of irrigated agriculture.* Dordrecht, Kluwer Academic Publishers, pp. 193–209.

Swart, R.J., Raskin, P. & Robinson, J. 2004. The problem of the future: sustainability science and scenario analysis. *Global Environmental Change,* 14 (2004) 137–146

Taleb, N. 2008. The Black Swan: *The impact of the highly improbable.* UK, Penguin Books.

Taleb, N. 2012. *Antifragile: How to live in a world we don't understand.* UK, Penguin Books.

Tarboton, D.G., Horsburgh, J.S., Maidment, D.R., Whiteaker, T., Zaslavsky, I., Piasecki, M., Goodall, J., Valentine, D. & Whitenack, T. 2009. Development of a community hydrologic information system. Eighteenth World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. In: Anderssen, R.S., Braddock, R.D., Newham, L.T.H. (Eds.): *Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation,* pp. 988e994. (Available at: http://www.mssanz.org.au/modsim09/C4/tarboton_C4.pdf). Accessed 18 April 2016.

Thaler, R.H. & Sunstein, C.R. 2008. N*udge: Improving decisions about health, wealth, and happiness.* USA, Yale University Press.

Tropp, H. 2005. *Developing Water Governance Capacities.* Feature Article. Stockholm, UNDP Water Governance Facility/SIWI.

Turner, K., Georgiu, S., Clark, R., Brouwer, R. & Burke, J. 2004. *Economic valuation of water resources in agriculture. from the sectoral to a functional perspective of water resources management. FAO Water Reports 27,* Rome, FAO.

UNDP. 2003. *Bridging the gap.* New York, United Nations Development Programme. (Available at:)

UNDP. 1997. *Governance for sustainable human development,* New York, UNDP. (http://mirror.undp.org/magnet/policy/). Not found 18 April 2016.

UNDP. 2009. P*lanning a governance assessment: A guide to aproaches, costs and benefits.* (Available at: http://www.undp.org/content/rbas/en/home/presscenter/events/2012/November/regional_governance_week/_jcr_content/centerparsys/download_8/file.res/Planning%20a%20governance%20assessment.pdf). Accessed 18 April 2016.

UNDP. 2013. User's Guide on Assessing Water Governance. (Web site: http://www.watergovernance.org/documents/WGF/Reports/20058-UNDP-Assessing-water_web.pdf). Accessed 18 April 2016.

USGS. 2013. Groundwater flows. (Available at: http://www.usgs.gov/water/). (Cited in December 2013; Accessed 18 April 2016). United States Geological Survey.

Unsworth, S. 2009. What's politics got to do with it? Why donors find it so hard to come to terms with politics, and why this matters. *Journal of International Development,* 21: 883-894.

UN-WATER. 2013. Water security and the global water agenda: *A UN-Water Analytical Brief.* (Available at: http://www.unwater.org/downloads/watersecurity_analyticalbrief.pdf). Accessed 18 April 2016.

Valters, C. 2015. *Theories of change: Time for a radical approach to learning in development.* London, Overseas Development Institute. (Available at: http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9835.pdf). Accessed 18 April 2016.

van Halsema, G.E. & Vincent, L. 2012. Efficiency and productivity terms for water management: A matter of contextual relativism versus general absolutism. *Agricultural Water Management,* 108, 9– 15.

Vivoni, E.R., Rango, A, Anderson, C.A, Pierini, N.A, Schreiner-McGraw, A.P., Saripalli, S. & Laliberte, A.S. 2014. Ecohydrology with unmanned aerial vehicles. *Ecosphere Volume, 5*(10) v Article 130.

Vrugt, J.A. 2016. Markov chain Monte Carlo simulation using the DREAM software package: Theory, concepts, and MATLAB implementation. *Environmental Modelling and Software,* 75. (Available at: DOI:http://dx.doi.org/10.1016/j.envsoft.2015.08.013). Accessed 18 April 2016.

Ward, F.A. & Lynch, T.P. 1996. Integrated river basin optimization: Modeling economic and hydrologic interdependence. Water Resources Bulletin 32(6): 1127-1138.

Warner, J. 2005. Multi-stakeholder platforms: integrating society in water resource management? *Ambiente & Sociedade* 8 (2): 17–28.

Warner, J. 2006. More sustainable participation? Multi-Stakeholder Platforms for Integrated Catchment Management. *International Journal of Water Resources Development* Volume 22, Issue 1.

WageningenUR. 2013. *Semi-structured interviewing.* MSP Resource Portal, Centre for Development and Innovation, Wageningen University. (Available at: http://www.mspguide.org/tools-and-methods). Accessed 3 May 2016.

Weber, M. (translator), Roth, G. & Wittich, G. 1968. *Economy and society: An outline of interpretative sociology,* New York, Bedminister.

Westerberg, I,K. & McMillan, H.K. 2015. Uncertainty in hydrological signatures. *Hydrol. Earth Syst. Sci.,* 19, 3951–3968, 2015. (Available at: http://www.hydrol-earth-syst-sci.net/19/3951/2015/hess-19-3951-2015.pdf). Accessed 18 April 2016.

Whitty, C. & Dercon, S. 2013. *The evidence debate continues.* People, Spaces, Deliberation. The World Bank. (Available at: http://blogs.worldbank.org/publicsphere/evidence-debate-continues-chris-whitty-and-stefan-dercon-respond-dfid). Accessed 18 April 2016.

Willardson, L.S., Allen, R.G. & Frederiksen, H.D. 1994. Universal fractions and the elimination of irrigation efficiencies. In: Proceedings *Thirteenth Technical Conference, US Commission on Irrigation and Drainage*, Denver, CO, 19–22 October 1994.

Woodhill, J. 2010. Multiple actors: Capacity lives between multiple stakeholders. In Ubels, J., Naa-Aku Acquaye-Baddoo and Fowler, A. (Eds). *Capacity Development in Practice. London, Earthscan.*

Woolcock, M. 2013. *Using case studies to explore the external validity of 'complex' development interventions.* UN-WIDER Working Paper No. 2013/096.

Woolhiser, D. A. & D. L. Brakensiek. 1982. Hydrologic System Synthesis. In Haan, C.T., Johnson, H.P. & Brakensiek, D.L. *Hydrologic Modeling of Small Watersheds.* ASAE Monograph No. 5.

World Bank. 2007. Tools for institutional, political, and social analysis of policy reform: A sourcebook for development practitioners. (Available at: http://siteresources.worldbank.org/EXTTOPPSISOU/Resources/1424002-1185304794278/TIPs_Sourcebook_English.pdf). Accessed 18 April 2016.

World Bank. 2009. *Problem-driven governance and political economy analysis: Good practice framework*. (Available at: http://siteresources.worldbank.org/EXTPUBLICSECTORANDGOVERNANCE/Resources/PGPEbook121509.pdf). Accessed 18 April 2016.

World Bank. 2011. *How-to notes: Political economy assessments at sector and project levels.* (Available at: http://capacity4dev.ec.europa.eu/political-economy/document/how-notes-political-economy-assessments-sector-and-project-levels). Accessed 18 April 2016.

World Bank. 2013. *World Development Report 2014: Risk and Opportunity—Managing Risk for Development*. Washington, DC: World Bank.

WWAP (World Water Assessment Programme). 2012. *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk. Paris,* UNESCO. (Available at: http://unesdoc.unesco.org/images/0021/002156/215644e.pdf). Accessed 18 April 2016.

Zaccaria, D., Oueslati, I., ·Neale, C.M.U., Lamaddalena, N., Vurro, M. & Pereira, L.S. 2010. Flexible delivery schedules to improve farm irrigation and reduce pressure on groundwater: a case study in southern Italy. Irrig. Sci. 28, 257–270.

Zeitoun, M. & Warner, J. 2006. Hydro-hegemony – a framework for analysis of trans-boundary water conflicts. **Water Policy 8** (2006) 435–460. (Available at: http://www.uea.ac.uk/polopoly_fs/1.147026!ZeitounWarner_HydroHegemony.pdf). Accessed 18 April 2016.

ANNEX 1. GLOSSARY

The following definitions are relevant to the sourcebook:

Access refers to both the biophysical and societal aspects of gaining access to sources of water and/or water services. It is common for the access of water users and uses to vary over space and time and according to water use.

Accountability: A government is accountable for decisions, laws and public expenditure affecting its citizens. Citizens are accountable for their behaviour and the actions they take. Accountability is different from transparency in that it prompts positive or negative feedback after a decision or action, while transparency can also prompt positive or negative feedback before or during a decision or action.

Action research is either research initiated to solve an immediate problem or a reflective process of iterative adaptive problem solving led by individuals working with others in teams or as part of a 'community of practice'.

Adaptive management is a type of management in which actions, strategies and plans are continually adjusted in the light of new information or evidence.

Awareness-raising is the process by which individuals or organizations increase their knowledge especially in matters that have actual or perceived relevance to them.

Appropriate imprecision recognizes that in conventional water assessments, much of the information collected has a degree of precision that is really unnecessary and/or is inconsistent (in terms of precision) with other information being collected.

Bayesian Networks provide a relatively simple method of representing and analysing probabilistic relationships. Bayesian Networks are based on the Bayesian theorem, which sets out to describes how the conditional probability of each of a set of possible causes for a given observed outcome can be computed from knowledge of the probability of each cause and the conditional probability of the outcome of each cause.

Beneficial consumption of water (in agriculture) is the part of water withdrawn from its source for irrigation that is either consumed by crops as a result of transpiration or captured as biomass. Non-beneficial consumption is the part of water withdrawn from its source that evaporates from the soil without contributing to biomass production.

Beneficial use of water: The use of water for purposes that have clear and tangible benefits, such as for household uses, irrigation, industrial processing and cooling, hydropower generation, recreation and navigation. Depending on context, beneficial use may include maintaining river levels for environmental purposes, diluting wastewater flows and sustaining wetlands, preventing saltwater incursions in estuaries.

Biophysical: In these guidelines the term biophysical encompasses soils, geology, geomorphology, hydrology and hydrogeology; climate; flora, fauna and aquatic ecosystems; human settlement patterns and the physical results of past and present human activity such as farming systems and other land-use management systems, water-related infrastructure and drainage or water treatment systems).

Capacity building is a process by which individuals or institutions develop and improve their knowledge, skills, competencies and abilities in areas that are important to them. Capacity Building can also include activities that aim to create a favourable enabling environment using water accounting and auditing.

Civil works refers to the infrastructure created or constructed for the benefit or use of the general public (e.g. water supply systems).

Community of Practice (CoP) is a self-organizing group of people who share a common interest for, for example, some aspects of WASH service delivery. Important characteristics of CoPs include an interest in learning related to priority issues and a high-level of trust and a willingness to share information. A similarity between CoPs and learning alliances is that they can both be considered to be institutional structures as well as processes specifically focus on learning.

Consumptive use of water is that part of water withdrawn from its source for use in a specific sector such as for agriculture, industry or domestic use that will not become available for re-use because of evaporation, incorporation into products, drainage directly to the sea or removal in other ways from freshwater sources. The part of water withdrawn that is not consumed in these processes is called return flow.

Data mining is the process of accessing and searching online databases for information that may be of value, for example, during a water accounting and auditing process.

Demand management is the use of price, quantitative restrictions, and other devices to manage demand for water of different water users and uses.

Demand, in economic terms, is an expression of willingness to pay for goods or services. Non-economists often understand demand for water to be the same as needs or requirements for water. In the context of water accounting and auditing, demand for water is understood to be somewhere between these two extremes, i.e. an expression of need for water but based on an understanding and acceptance of the costs (monetary and non-monetary) of meeting the needs of different water users and uses (in space and time).

Digital Elevation Model or **DEM** is the term that refers to any digital representation of a topographic surface. However, it is most often used to refer specifically to a raster or regular grid of spot heights.

Drivers (Drivers of change) are factors that cause change or affect and shape the future.

Effectiveness is the extent to which actual performance compares with targeted performance

An Enabling environment comprises the international, national, district and local policies and legislation that constitute the 'rules of the game' and enables stakeholders and others to participate in, for example, a water accounting and auditing process.

Environmental flows are the flow regimes needed to maintain aquatic ecosystems locally, in riparian areas and downstream.

Exploitable water (also called manageable water resources or water development potential) is the volume of water potentially available for consumptive water-use sectors such as for agriculture, industries or municipalities. An attempt to quantify that part of a country's total renewable water resources that is effectively available to be withdrawn, depending on factors that include the economic, political and biophysical feasibility of water storage and bulk transfer systems; groundwater extraction; restoring and protecting ecosystem services; and maintaining flows for navigation. The level of exploitable water varies with the level of the country's economic development, infrastructure, water variability and quality, and the trade-offs between competing water users and uses.

Equity is the degree to which different individuals or groups within a community or society at large benefit from a good or service. For projects and programmes, taking an equity-based approach means paying special attention to the specific needs of the most marginalised members of society who may otherwise be excluded from benefits. In the context of water accounting and auditing, equity relates to fairness in terms of access to water for domestic and productive uses and, as such, does not mean equal access. Determining fair and/or reasonable access to water is a highly political process.

Externality is the unintended real, both monetary and non-monetary, side effect of one party's actions on another party, which is often ignored in strategy development and planning processes or in decision-making by the party causing the effects.

Facilitation/facilitator is someone who skilfully helps a group of people understand their common objectives and plan to achieve them without personally taking any side of the argument. The facilitator will try to assist the group achieve a consensus on any disagreements that pre-exist or emerge during, for example, stakeholder dialogues so that this dialogue has a strong basis for future action.

Freshwater is naturally occurring water on the Earth's surface in glaciers, lakes and rivers and underground in aquifers. Its key feature is a low concentration of dissolved salts. The term excludes rainwater, water stored in the soil, untreated wastewater, seawater and brackish water. In this report, when not otherwise specified, the term water is used as a synonym for freshwater.

Gender relates to the different roles played by men and women, boys and girls. A gender-based approach means dealing explicitly with these differences. Often it also implies an element of empowerment of women. Gender is often bundled with equity (see above) with which it is closely related.

Gender mainstreaming ensures that gender inequities are considered during stakeholder dialogue and the decision-making processes.

Governance is defined as in the frequently cited: "The exercise of political, economic and administrative authority in the management of a country's affairs at all levels. Governance comprises the complex mechanisms, processes, and institutions through which citizens and groups articulate their interests, mediate their differences, and exercise their legal rights and obligations"(UNDP 1997).

Governance assessment is essentially a generic methodological approach that can be used for assessing governance (OECD, 2009).

Government plays a key role in the water sector including stewardship of water resources, which is typically a central government function, and delivery of water services, which is typically a local government function. Although few people would directly equate governance with government, in practice the idea of governance, as a set of desirable principles, has taken firm hold. Indeed, for many people, good governance is shorthand for absence of corruption particularly in the exercise of power.

Groundwater occurs underground and can be abstracted from wells using pumps or buckets. Groundwater exists in the spaces between soil (pores) and rocks, in cracks and fissures. Unlike soil moisture it is not bound to the soil/rock and is free to flow under the force of gravity – for instance into a well, but also into rivers.

Information includes data or knowledge that is captured, stored and shared in written or digital forms and includes audio or video recordings, in diagrams and pictures.

Information management is the process of gathering, storing, sharing and analysing information needed for a specific purpose, such as planning or making management decisions.

Infrastructure, in the context of water accounting and auditing, refers to the systems both hardware and software needed for extracting, diverting, storing, treating and conveying water for different purposes.

Institutions include the rules, norms and conventions governing human interaction. Institutions may be formal in the sense of constitutional rules, codified laws and bureaucratic rulebooks, or informal in the sense of social and cultural norms. Political economy analysis pays particular attention to the informal norms that underpin social hierarchies, create and perpetuate power structures and generate reciprocal obligations. In settings where formal institutions are weakly embedded and enforced, informal norms often explain how things really get done.

Institutional level refers to the tiers of political and administrative decision-making on a scale that runs from the local level to the national and international levels. In administrative terms, local level is usually considered to be the level of small towns, villages and below, whereas the intermediate level is considered to be the district and governorate level.

Irrigation efficiency: Generally, 'water use efficiency' is a dimensionless ratio that can be calculated at any scale and used for different classes of water supply and use such as in an inter-basin transfer system, a town water supply network. In the agicultural sector, it is referred to as irrigation efficiency (IE) and used to assess and monitor system losses that can be classified as non-beneficial water use fractions that may be non-recoverable (e.g. evaporation from a canal) or recoverable (e.g. seepage from unlined canals). The attractiveness of irrigation efficiency as an indicator is embedded in its constituent parts that distinguish conveyance efficiencies from application efficiencies. The net result for a specified domain is that IE neatly distinguishes the irrigation engineering/management efficiency from the farmer/agronomic efficiency (van Halsema and Vincent, 2012). However, it should be noted that IE estimates are less comparable than sometimes implied because they are scale dependent, both in time and space – this hampers comparison of IE values, across scales, time-frames and localities (Van Halsema and Vincent, 2012).

Learning alliance is a group of individuals or organizations with a shared interest in innovation and its scaling-up related to a concern or issue of mutual interest. Learning alliances are comprised of a series of structured platforms at different institutional levels including national, river basin, city and community, designed to facilitate horizontal and vertical information sharing, and thus speed up the process of identification, adaptation and uptake of new innovations.

Management is the decision-making process whereby a plan or a course of action is implemented. Planning forms part of this process as does the allocation of resources and the resolutions of conflicts of interest. Effective management is only possible if managers have access to reliable information.

Marginalised or marginalisation refers to the overt or covert trends within societies whereby those perceived as lacking desirable traits, or deviating from the group norms, tend to be excluded by wider society. Marginalised social groups tend to be poor and have limited access to water for both domestic and productive purposes. They also tend to be excluded from and/or are unable to influence decision-making processes that influence their access to safe water.

Metadata is data that describes other data. For example, metadata for a water governance report could include report author and organization; date drafted; name of report; and analytical framework used. Or metadata for rainfall data could include responsible organization, number, type and grid references of rain gauges, methodology used to convert point measurements to areal estimates and an estimate of uncertainties.

A **model** is a representation of a biophysical and/or societal system through the use of mathematical equations and algorithms.

A **modelling system** is a computer program or software package that is typically built around a model, or number of models and can access input data (e.g. from a database); can generate output in different forms and formats (e.g. as a map, a table or a probability distribution) and has a user interface to number of models and input and output systems to facilitate application.

A **model application** is the use of a model or models to address defined questions such as what if questions, and to generate outputs (e.g. estimates of river flows in an ungauged catchment, estimates of the marginal benefits of specified water use in space and time).

Model calibration is an iterative process of fine-tuning the model to a set of field data, preferably data that were not used in the model construction.

Model validation is achieved through calibration and verification so that the model is an accurate representation of the real system or catchment being modelled.

Model verification is the statistical comparison of the model output to additional data collected under different forcing and boundary conditions.

Monitoring and Evaluation may often become blurred in practice, but it is important to understand the distinction between them. Monitoring is the continuous assessment of project (or programme) implementation in relation to agreed schedules and the use of inputs, infrastructure and services by beneficiaries. Evaluation, on the other hand, is the periodic assessment of a project's (or programme) relevance, performance, efficiency, and impact (both expected and unexpected) relative to its stated objectives.

Optimal ignorance means understanding the difference between what is worth knowing and what is not. Use of this principle avoids the collection of more information than is really needed.

Ownership is the state of either exclusive or shared possession or control over property, which may be an object, land, water, intellectual property or similar.

Perceptual model is a qualitative description of the biophysical and societal processes or cause and effect mechanisms that are perceived to be important in specified domains. As information and evidence becomes available, perceptual models can be updated and improved.

Political economy was defined by Adam Smith as the social science that deals with political science and economics as a unified subject; the study of the interrelationships between political and economic processes.

Political economy analysis is concerned with the interaction of political and economic processes in a society: the distribution of power and wealth between different groups and individuals, and the processes that create, sustain and transform these relationships over time.

Process documentation, in the context of water accounting and auditing, focuses on monitoring and documenting qualitative processes such as the way in which water-related decisions are made.

Return flow is the part of the water withdrawn from its source which is not consumed and returns to its source, or to another body of groundwater or surface water. Return flow can be divided into non-recoverable flow (flow to salt sinks, uneconomic groundwater or flow of insufficient quality) and recoverable flow (flow to rivers or infiltration into groundwater aquifers).

Riparian areas (or ecosystems) have distinctive characteristics that are a strongly influenced by the saturated or near saturated soil conditions. Riparian ecosystems occupy the transitional area between terrestrial and aquatic ecosystems. Typical examples include floodplains, wetlands, stream banks and lakeshores.

Sanctioned discourse is a particular view or opinion that is politically acceptable at a specific point in time. To disagree with or challenge this view or opinion could come at the cost of exclusion from the groups that have the power, in one way or another, to damage careers or sanction individuals or organizations.

A **Scenario** is a plausible and internally consistent description of a possible future situation, a story about the way an area or domain of interest might turn out at some specified time in the future. Scenario building is the process of developing scenarios.

A **Strategy** is a medium to long-term planning framework within which specific activities are described and plans implemented. Over time, an effective strategy should lead to a vision being achieved.

The term **Societal** is used in this sourcebook to encompass formal and informal institutions; politics, the wider political economy and socio-political legacies; economics and behavioural economics; formal and informal legislation; and relevant social and cultural factors or norms.

Stakeholders in the context of water accounting and auditing, fall into three main groups: 1) Those with the power and funds to implement policies and programmes; 2) Those affected by these policies either directly or indirectly; and 3) Those that have access to information, knowledge and the ability and capacity to influence, support and facilitate way in which policies and programmes are formulated and implemented.

Key stakeholders are those stakeholders who are most important to the water accounting and auditing process and the effective use of findings, outputs and recommendations. Key stakeholders must be brought into the process, and efforts should be made to ensure their sustained active involvement.

Stakeholder dialogue, in the context of water accounting and auditing, refers to mediated interactions and discussions between different stakeholders that aim to resolve competing interests and competing views concerning the nature and severity of water supply problems and, as a next step, reaching a consensus on how best to tackle these problems in a way that is efficient, equitable and sustainable.

Stakeholder platform also multi-stakeholder platform, in the context of water accounting and auditing, provides a mediated forum for stakeholder dialogue, conflict resolution and integrated planning. In a practical sense, a stakeholder platform can take the form of a committee, a workshop, a village meeting or even a conference call. The key aspect is that mediation using a range of tools and methods is leading to constructive dialogue amongst stakeholders.

Strategy is a medium to long-term planning framework within which specific activities are described. Over time an effective strategy should lead to achievement of a specified vision.

Supply enhancement (also called supply management or supply augmentation) is a set of actions or management strategies to increase water supply, either through water resources development and (construction of water infrastructure or groundwater development) or augmentation of available water resources through development of non-conventional sources of water, such as desalination of sea water or re-use of treated wastewater.

Theory of change at its most basic, identifies and documents a set of assumptions related to a given change process. Theories of change can also consider the influence of a range of socio-cultural, political and behavioural factors or mechanisms on a given change process.

Trade-off, in economic terms, is what must be given up, and what is gained, when an economic decision is made. Although the terms trade-off and externality are often interchanged, the main difference is that a trade-off is an intended loss or negative impact whereas an externality is unintended.

Transparency: See accountability

Triangulation is a relatively simple method of checking the accuracy of biophysical and societal information based on comparing information elicited from three or more independent sources. Triangulation is akin to corroboration and an essential methodological feature of water accounting and auditing.

Uncertainty is a statistically defined discrepancy between a measured quantity and the true value of that quantity that cannot be corrected by calculation or calibration. Uncertainty is an inevitable part of the assertion of knowledge.

The **unsaturated zone** is immediately below the land surface, where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.

Up-scaling is the process by which relatively small-scale pilot studies are scaled up to cover larger areas. Up-scaling often involves addressing issues relating to externalities, sustainability, costs and institutional capacity that are not apparent when working with small-scale pilots

Variability in statistics, is a measure of statistical dispersion and the spread of a data set around the average or expected value. In many cases, higher levels of variability are linked to higher levels of uncertainty and risk.

Vision is a concise description of a desired future state. Visions provide a picture of how we would like the world, or our water resources and services, to be at some future time. Consensus on this vision is required before a strategy is developed.

Visualisation refers to any technique for creating images, diagrams, or animations to communicate messages, raise awareness or similar.

Water accounting is the systematic study of the current status and future trends in water supply, demand, accessibility and use within specified spatial and temporal domains. The concept of water accounting is based on the argument that knowledge of the current status of water resources and trends in demand and use is a precondition for successful water management.

Water auditing goes one step further than water accounting by placing trends in water supply, demand, accessibility and use in the broader context of governance, institutions, public and private expenditure, legislation and the wider political economy of water of specified domains.

Water governance, at its simplest, relates to 'who gets what water, when and how' (Tropp, 2005). The Global Water Partnership's broad definition of water governance provides a similar, if less snappy, definition: 'the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society' (Rogers and Hall, 2003).

Water management refers to planned development, allocations, distribution and use/ reuse of water resources, in accordance with predetermined objectives and with respect to both quantity and quality of the water resources.

Water productivity is the quantity (mass, calories) or value of output (including services) in relation to the volume of water used to produce this output. Crop water productivity is simply the amount (kg or calories) or value of product per unit of water supply (cubic metre).

Water use is any deliberate application or use of water for a specific purpose. There is an important distinction between consumptive use (see earlier definition) and non-consumptive use. Important non-consumptive uses include navigation, recreation, waste assimilation and dispersion. Although hydropower and power station cooling is not a major net consumptive user of water, they do have a major impact on the hydrological cycle, and release water at times and temperatures that impose costs on other water users. Reservoirs also cause evaporation losses.

Water use efficiency in engineering terms, is the ratio between the amount of water actually used for a specific purpose and the amount of water withdrawn or diverted from its source, such as a river, aquifer or reservoir, to serve that use. It is dimensionless and can be applied at any scale. In this report, 'efficient use of water' is understood in more general economic terms, as the use of water to maximise the production of goods and services. Efficient use of water in agriculture can be achieved by reducing water losses in transmission and distribution, increasing crop productivity or diverting water towards higher-value crops (intra-sectoral allocation). But just because an agricultural use of water becomes more efficient does not mean that water is 'saved'. In the quest for greater 'efficiency', it is important to take a broad view (e.g. at basin level), recognizing the contribution that so-called 'losses' can make to the productivity of other users and in other parts of the water cycle.

Water scarcity is an imbalance between supply and demand of freshwater in a specified domain (country, region, catchment, river basin, etc.) as a result of a high rate of demand compared with available supply, under prevailing institutional arrangements (including price) and infrastructural conditions. Its symptoms are: unsatisfied demand, tensions between users, competition for water, over-extraction of groundwater and insufficient flows to the natural environment. Artificial or constructed water scarcity refers to the situation resulting from over-development of hydraulic infrastructure relative to available supply, leading to a situation of increasing water shortage.

Water shortage is a shortage of water supply of an acceptable quality; low levels of water supply, at a given place and a given time, relative to design supply levels. The shortage may arise from climatic factors, or other causes of insufficient water resources, a lack of, or poorly maintained, infrastructure, or a range of other hydrological or hydro-geological factors.

Water services delivery is a user or customer-oriented activity. Water service delivery activities are carried out by organizations and are oriented towards meeting users or customer needs and expectations. In the context of water accounting and auditing, water services encompass all potential water users and uses for example domestic, agricultural, industrial, commercial and municipal users and the environment.

Water withdrawal is the gross volume of water abstracted from streams, aquifers or lakes for any purpose (e.g. irrigation, industrial, domestic, commercial.

A **Wicked problem** is a problem that is difficult or impossible to solve for reasons that include incomplete or contradictory knowledge and the number of people and opinions involved.

ANNEX 2. CASE STUDIES

CASE STUDY 1. SPATIAL DISTRIBUTION OF WELLS, UNGARANIGUNDLA VILLAGE, KURNOOL DISTRICT ANDHRA PRADESH, INDIA

FIGURE A.
Land use in 2012

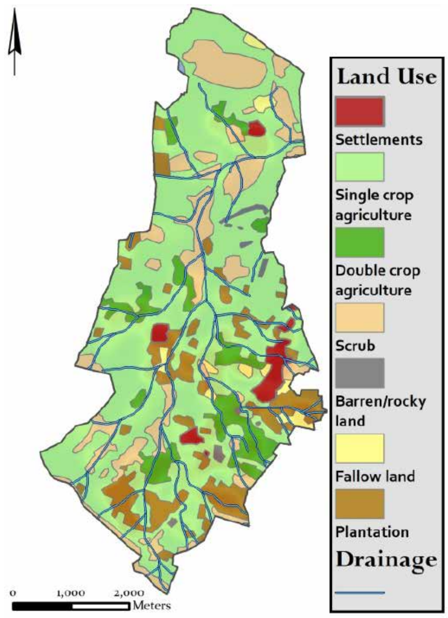
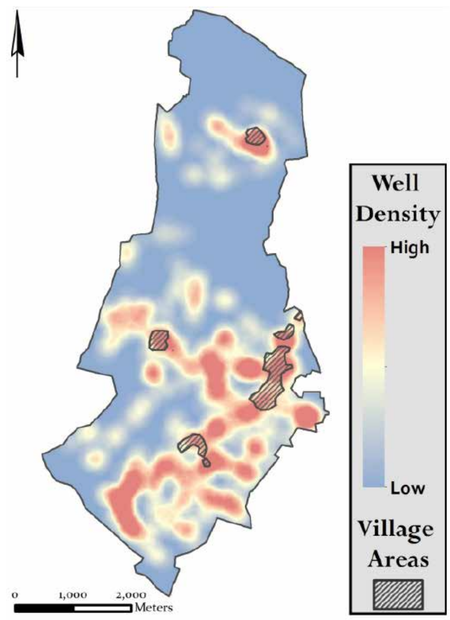
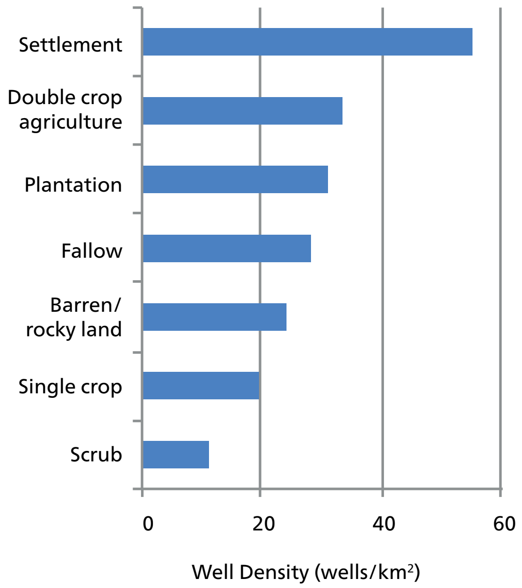


FIGURE B
Well density "heat" map



Ungaranigundla village is experiencing increasing water scarcity as a result of increased groundwater-based irrigation, intensification of rainfed farming and falling groundwater levels. Figure A shows the village's land use in 2012 – this is typical for semi-arid areas of southern India underlain by hardrock geologies. High rates of private investment in well construction during the last 20-30 years has resulted in an average well density in this village of 24 functional or partially functional wells per km2. However the distribution of wells is far from uniform (see Figure B). Highest density of wells is along the drainage lines where groundwater recharge rates are highest and where soils are deeper and more productive. This is also where settlements and areas of irrigated double-cropping or plantations are located. In contrast, the lowest well density (less than 10 wells per km^2) correlates with scrubland that is located in rocky interfluve areas that have poor soils. Intensive watershed development in recent years has improved groundwater recharge along drainage lines and capture of rainfall by rainfed farming systems. But this has come at the cost of reduced runoff and less water availability for downstream water uses and users.

TABLE X.
Well density per land use



Source: Batchelor (2013)

CASE STUDY 2. SPATIAL DISTRIBUTION OF WATER ACCESS/ USE, EXPENDITURE AND POWER VENKATAPURAM VILLAGE, KHAMAM DISTRICT, ANDHRA PRADESH, INDIA

FIGURE A.
Venkatapuram's public and private water-supply infrastructure

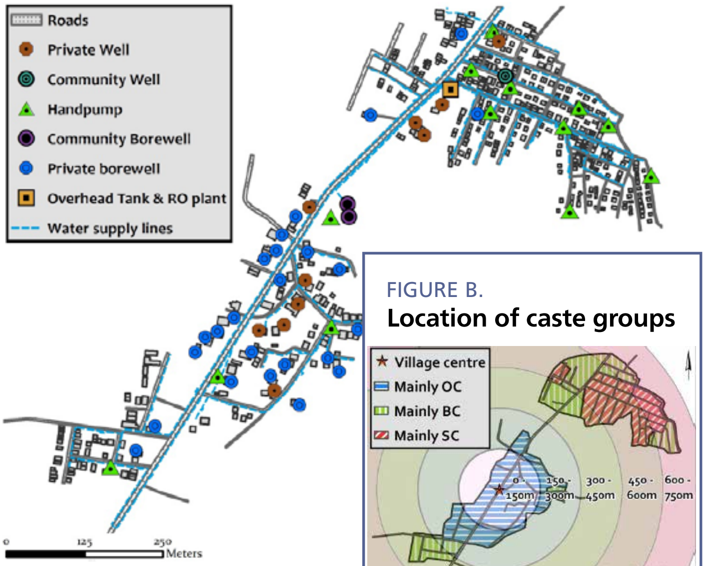


FIGURE B.
Location of caste groups

Despite several decades of reform the goal of equitable access to rural water services in rural India is as elusive as ever. The reality is that access to adequate and secure water services continues to be skewed spatially towards relatively better-off and more powerful social groups. Venkatapuram village is typical village in southern India in which during recent years there has been high levels of public and private investment in infrastructure (see Figure A) aimed at improving the quantity and quality of water services. However, it can be seen that private investment in borewell is highest in central areas (see Fig. D) of the village where the richer more powerful social group lives (i.e. Other Castes (OC). This group is also better served by the public water-supply system and they can better afford to pay for water from a reverse osmosis (RO) plant. In contrast the social groups (i.e. Backward Castes (BC) and Scheduled Castes (SC) living further from the centre of the village do not have private wells, nor can they afford to pay for treated water. Also because they live towards the tail-end of the public water-supply system they tend to suffer from typical "tail-end" water-pressure problems. Another concern is that groundwater extraction by increasing numbers of private wells has lowered the water table and led to failure of one of the two wells that feed the public water supply system.

FIGURE C.
Water use v distance from village centre

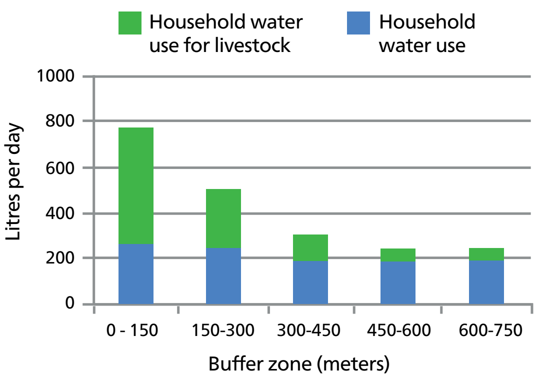
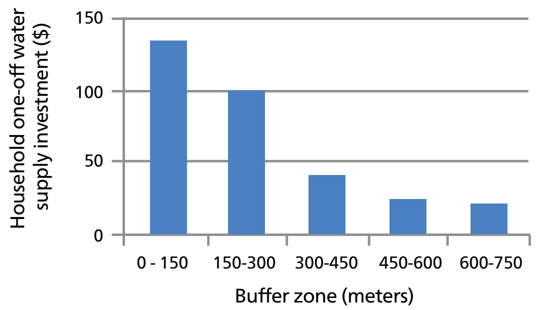
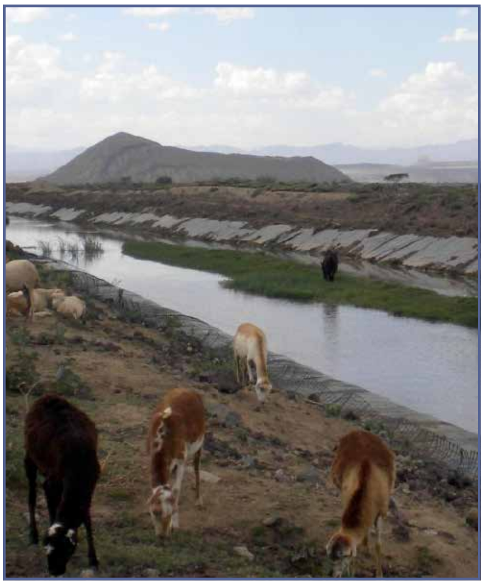


FIGURE D.
HH investment v distance from village centre



Source: Snehalatha and Batchelor (2013)

CASE STUDY 3. SURVEY OF IRRIGATION SCHEMES IN AWASH RIVER BASIN, ETHIOPIA



Accurate, spatially explicit information on irrigation, which is a key component of water accounting, is often unavailable, particularly in areas where uncontrolled abstraction represent a significant share of withdrawals. Awash River basin, in Ethiopia, is one of these areas:

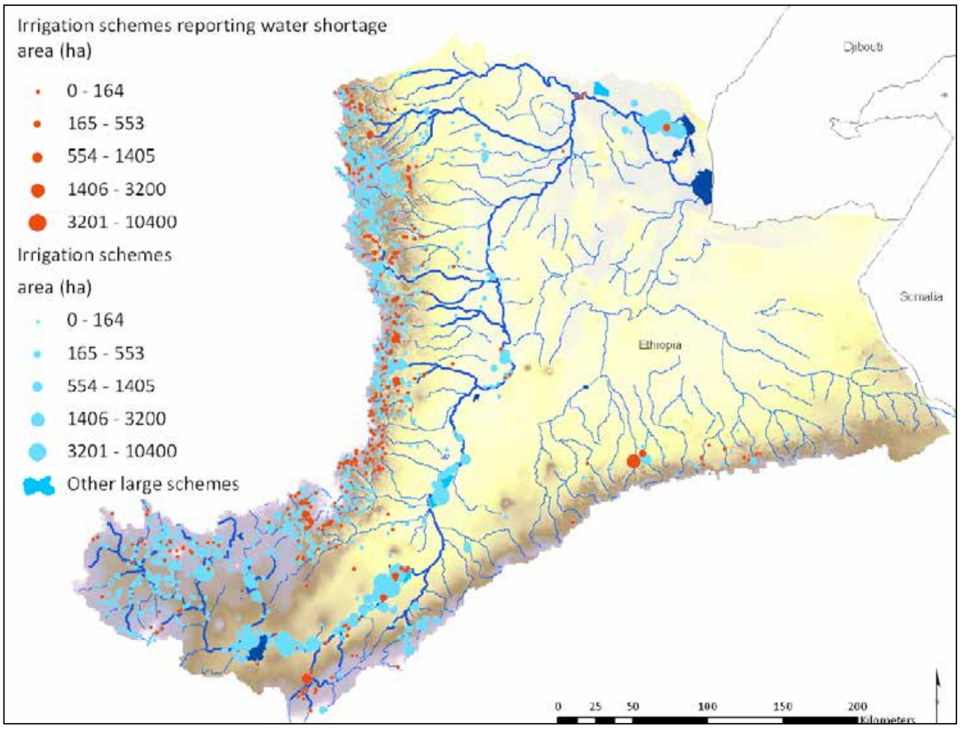
- abstraction are in most cases uncontrolled and information on extent of irrigated area is often outdated or inaccurate.
- poor knowledge on withdrawals and systems status is one of the reasons behind lack of management of water resources and water shortage reported by farmers.
- large public schemes are being implemented with limited analysis of suitability of the location nor of long term economic sustainability of such interventions.

With the aim of providing a sound baseline of agricultural water use, the Awash River Basin Water Audit project, carried out a detailed survey of irrigation schemes in collaboration with Ethiopian Federal and Regional Governments down to districts, and Basin authority, whose technicians were trained in agricultural water use data collection and reporting.

The survey covered 2,166 schemes, lasted for about 5 months, and involved nearly 160 trained surveyors and 15 supervisors, for an overall cost of about 95,000 USD, partially covered by Regional institutions and Awash river basin authority.

FIGURE A

Irrigation schemes reporting water shortage area (ha)



Source: FAO, 2013

FIGURE A.
Basin income under different scenarios (EPSMO project)

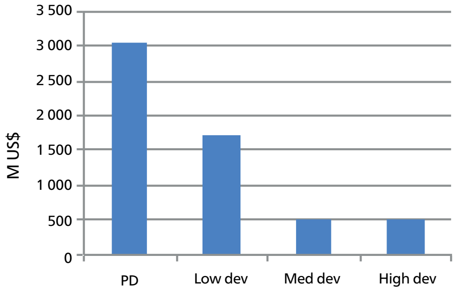
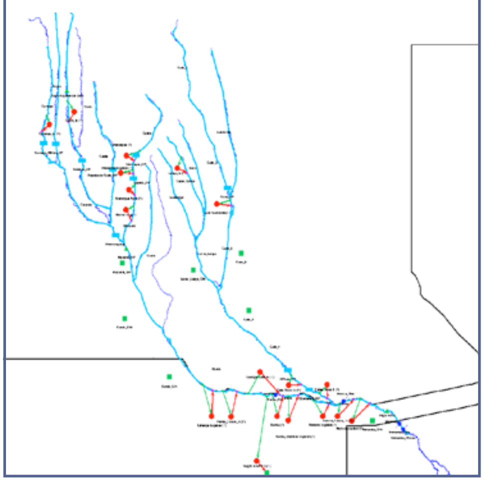


FIGURE B.
Schematic View of the WEAP application

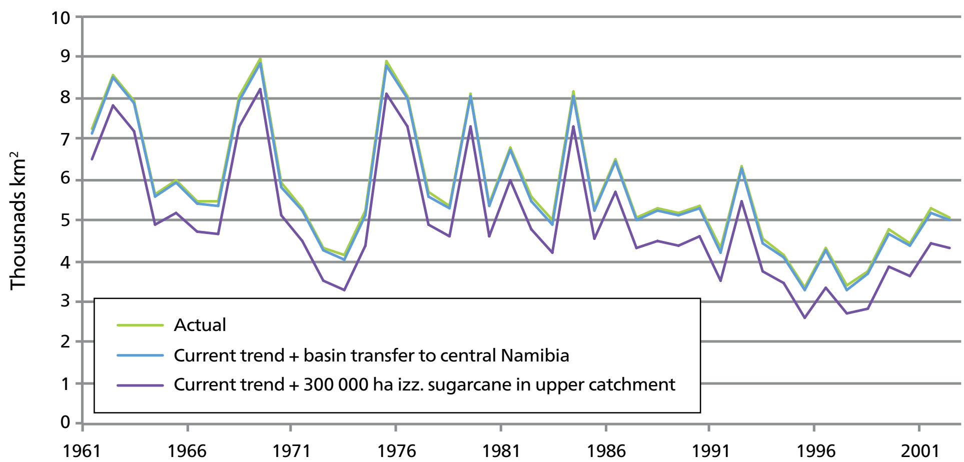


CASE STUDY 4. COMBINING DECISION SUPPORT TOOLS WITH SCENARIO BUILDING IN THE CUBANGO-OKAVANGO RIVER BASIN (ANGOLA, NAMIBIA AND BOTSWANA)

Scenario building can be used to evaluate "what if" questions and review the expected impact of relevant development options in combination with decision support tools. The Water Evaluation and Planning system (WEAP) was used during the Environmental Protection and Sustainable Management of the Okavango (EPSMO) project which developed Low, Medium and High Development scenarios for the basin. An economic evaluation of the water resources of the basin, including the highly income generating touristic area of the delta, was performed. Results indicated that Low, Medium, and High development scenarios, would increasingly and significantly reduce the income that people in the basin and its associated economies could derive from natural resources as compared to present day (PD) conditions, due to predicted reduced benefits from tourism relying on the wetland system (Barnes, 2009; FAO, 2014). In the ensuing Cubango-Okavango River Basin Water Audit (CORBWA), the need emerged to better define the Low, Medium and High development scenarios, and to qualify the relevance of sector specific development options. To that extent, an effort was made to estimate the impact of specific interventions on the extent of flooded area of the delta, by introducing a new calculated variable in the WEAP application. Results suggest impact of climatic variability (visible in the "Actual" scenario – yellow line in the graph below) being higher than those estimated for the development options identified in the exercise, including irrigation in the upper catchment (purple line) and water transfer to central Namibia (blue line).

The study recommendations also include i) allocation policies to manage the combined impacts of dry periods and increasing water development, and ii) more effective benefits sharing mechanisms.

FIGURE C.
Extent of maximum area flooded in the delta in selected development options



CASE STUDY 5. REMOTE SENSING BASED WATER ACCOUNTING (WA+) IN HELMAND RIVER BASIN, AFGHANISTAN

FIGURE A.

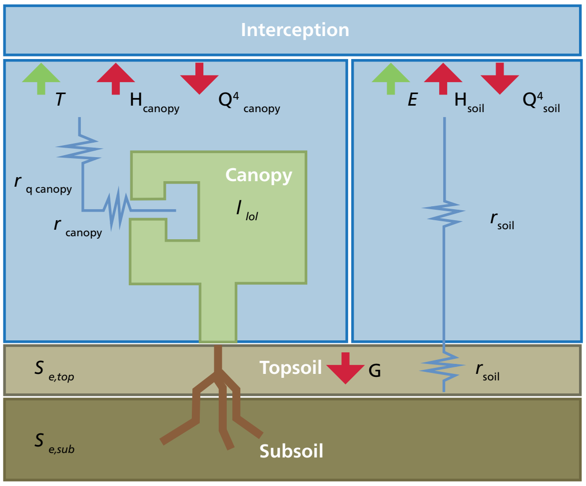
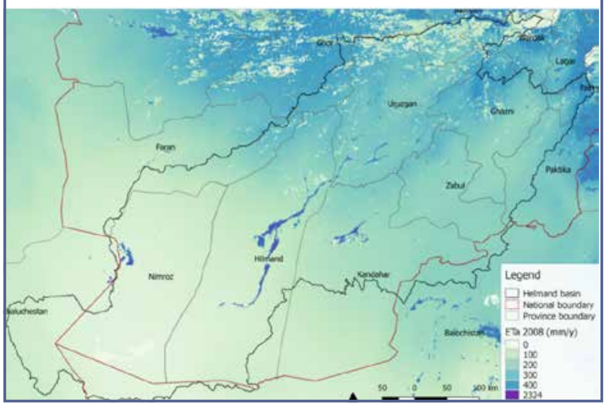


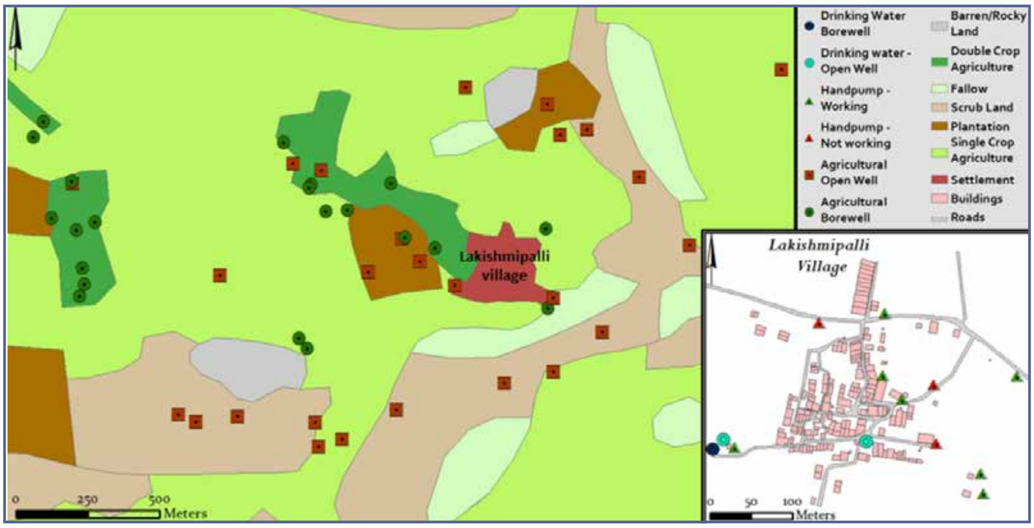
FIGURE B.
Actual evapotranspiration (mm/year)



Remote sensing (RS) based water accounting has been used and developed in recent years taking advantage of the increasing variety and accuracy of spaceborn sensors. These techniques aim at calculating evapotranspiration by solving the surface energy balance between incoming, absorbed and reflected energy. They have the advantage of being applicable without expensive field monitoring and data collection activities (although ground data significantly increase the quality of calibration and thus final results) and of being particularly suitable for monitoring conditions over time. But, at the same time, they are less suitable for assessing water use sectors not directly linked with land use, such as industrial, domestic or environmental uses. Water Accounting Plus (Bastianssen et al., 2014) is a RS based water accounting approach which assesses water balance components by land use category using publicly available data. It makes a distinction between beneficial and non-beneficial components of evaporation, transpiration and interception, and it expresses productivity per unit of land and per unit of water consumed. WA+ has been applied for FAO in the Awash River Basin in Ethiopia and the Cubango-Okavango River basin in Southern Africa using ET Look algorithm (Figure A.), in conjunction with traditional water accounts, In the Helmand River Basin in Afghanistan. WA+ study relied on Operational Simplified Surface Energy Balance (SEEBop), an evapotranspiration product provided for the study by USGS EROS data centre (Senay et al., 2013).SEEBop data were downscaled to 250 meters resolution using MODIS NDVI products on monthly time steps over five years (2007-2011). By processing other publicly available RS data, the study produced all layers of information (biomass, canopy cover, rainfall, interception) needed to compute , among others, water consumption (beneficial and non) and crop water productivity in the different land use classes. The availability of recent and detailed land cover data is key in applying this approach and being able to accurately report on WA components by land and water use category. The Helmand River basin was identified for applying WA+ also because of the availabilty of such high resolution land cover data (FAO, 2012). Accuracy of rainfall data also has a major impact on overall study quality and requires appropriate calibration.

CASE STUDY 6. COMBINING INFORMATION FROM DIFFERENT SOURCES AND PARTICIPATORY MAPPING OF WATER POINTS, LAKSHMIPALLI, ANDHRA PRADESH, INDIA

Water accounting involves acquiring, blending and analysing biophysical and societal information from a range of different sources. Much of this will be existing information that needs to be quality-controlled, updated and/or gap-filled. In almost all cases, this is best achieved with active stakeholder engagement and by making use of new technology global positioning system (GPS) devices. These devices provide an increasingly cheap method of collecting large amounts of relatively accurate georeferenced information that can add value to and increase confidence in existing information.



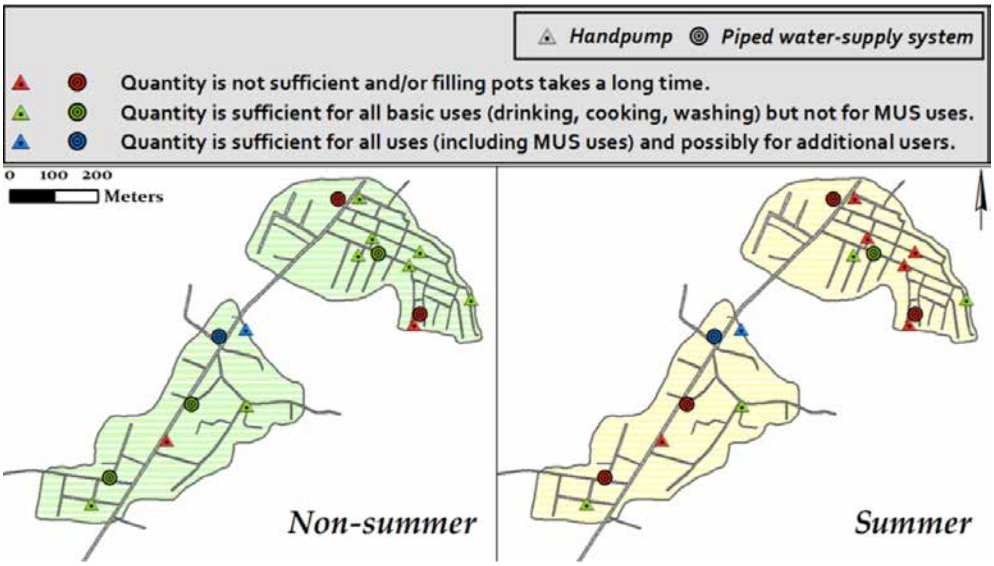
In this case study, land use information was acquired from India's National Remote Sensing Agency (see Figure A). Additional information on the location of wells in the whole study area and features in the built area of the village (see Figure B) was acquired using handheld GPS devices. The scales of the built and surrounding area surveys were of the order 1:1000 and 1:10,000. As part of this 2-day survey attribute information was also collected for each well (e.g. well type, depth, functionality and ownership/use details, water services levels etc). The case study highlights the following:

- Participatory mapping using GPS handsets or GPs-enabled smart phones: 1) Adds value to secondary information and 2) Is cost-effective and an excellent means of involving local stakeholders
- Surveys that encompass all groundwater sources (e.g. different well type) and demands/uses provide valuable insights into levels of inter-sectoral competition and the variability of water services experienced by different social groups in space and time.

CASE STUDY 7. USING SOCIAL ENQUIRY TO ASSESS THE ADEQUACY OF WATER SERVICES, VENKATAPURAM, ANDHRA PRADESH, INDIA

Social Enquiry methodologies are used during water accounting to: 1) Elicit information on the level of water services experienced by users of these services and 2) Gain insights into the social, cultural, philosophical and political value systems and other factors that influence attitudes and behaviour of individuals and communities. The Qualitative Information Systems (QIS) approach is one such methodology. QIS is based on ordinal scoring scales which convert qualitative information into numbers so that results can be analysed statistically and/or displayed easily on maps.

FIGURE A.
Water supply adequacy



QIS was used in Venkarapuram during focus-group discussions to elicit the perceptions of users regarding the adequacy of their two water supply systems (i.e. handpumps and a piped water supply system) during the non-summer and summer months. The main findings from the summer survey included: 1) The volume of water supplied by 5 out of 7 of the working handpumps in the northern part of the village was insufficient to meet the demands of all potential users/uses; 2) The volume of water supplied by the piped-water supply network was insufficient to meet the demands of all potential users/users at the tail ends of the network (i.e. essentially points furthest away from the centre of the village); and, 3) The piped-water supply network was a relatively better source of supply than handpumps. In contrast, the main findings from the non-summer survey included: 1) The overall adequacy situation was much improved, however, in the northern parts of the village users at the piped-water supply network had problems accessing sufficient water and 2) Handpumps were regarded as being a better source of water than the piped water supply network (i.e. user "water supply" preference switches between summer and non-summer from the piped-water supply network to the handpumps).

CASE STUDY 8. RAPID WATER ACCOUNTING TO ASSESS STATUS OF A MOUNTAINOUS CATCHMENT, WOOCHU, BHUTAN

Rapid water accounting was used in the Woochu catchment to: 1) Investigate concerns over perceived reductions in dry-season flows and increases in sedimentation in the Wang Watershed that could be linked to land use and climate change and 2) Demonstrate that rapid water accounting is a robust methodology that could be used effectively by the Royal Government of Bhutan as part of it's assessment and monitoring programmes. Over a 10-day period, national stakeholders, (1) Analysed existing hydrological and land use information and 2) Consulted and interacted with local stakeholders .

This case study indicated that the Woochu sub-catchment is in good condition. Dry-season flows are high and close to pristine levels. Similarly, indications are that water quality and sedimentation are not major issues. Hence, the main challenge in this sub-catchment is to identify and implement strategies and mechanisms that sustain this good condition. Options include: to 1) Use Woochu as reference catchment when modeling/monitoring the Wang Watershed and 2) To use PES schemes, based of hydropower generation , to support sustainable watershed management practices.

FIGURE A.
Precipitation 2005-2006

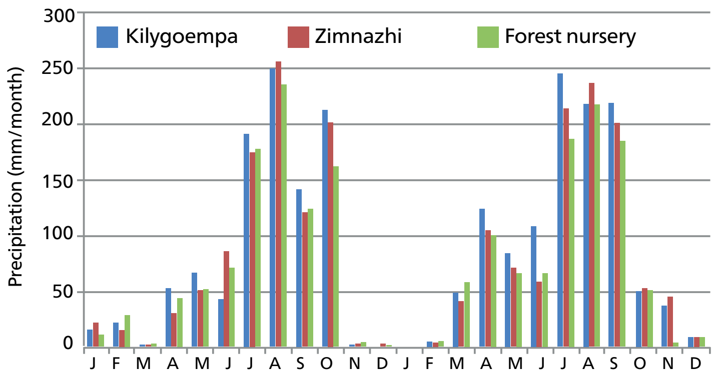


FIGURE B.
Land use above the two gauging stations

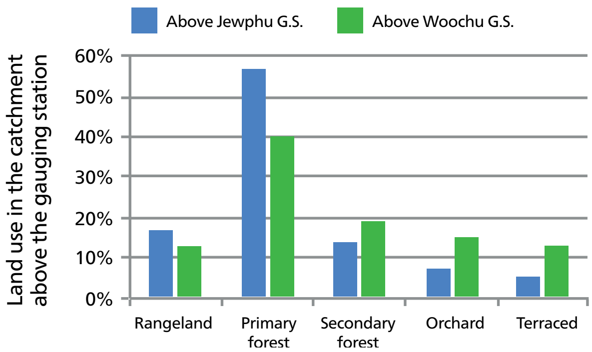
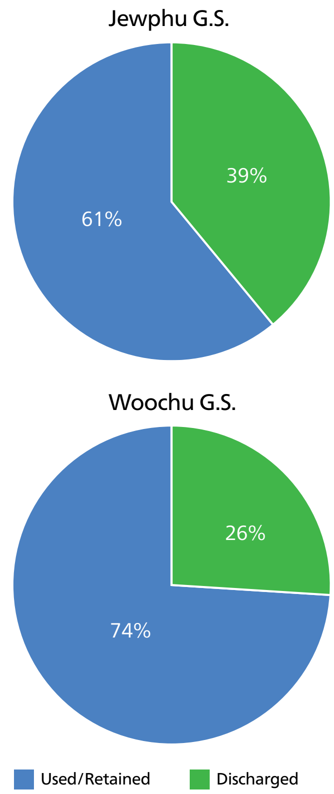
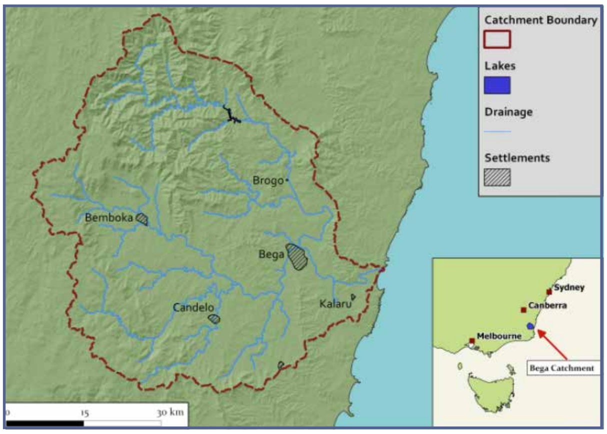


FIGURE C.
Surface water balance for areas above the gauging stations



CASE STUDY 9. ELUSIVE CONSENSUS OF A WATER SHARING PLAN, AUSTRALIA



The Bega and Brogo Rivers Area Water Sharing Plan (WSP) covers a coastal catchment in southern New South Wales that supports a diverse range of water users (such as hydro-power generation, urban supply, agriculture and food processing) that compete for water during times of shortage. NSW in the State of New South Wales establish rules for sharing water between the environmental needs of the river or aquifer and water users, and also between different types of water use.

Water Source	Change to water source rules	Justification
All plan area	The installation of new bores may be permitted closer than minimum distances if a hydrologic assessment can demonstrate that the impact of the new bores will be within acceptable limits	
Tangawangalo	The councils TDEL from Tangawangalo Weir during periods of very low flow will be set at 0.2 ML/day	A minimum flow of 0.2 ML/day is required to maintain pressure in the two 25 mm diameter pipelines. The panel thought that a daily extraction of 0.2 ML/day water reasonable to supply 44 properties
Mid Bega River sands	The mMid Bega sands will be included in Cl 77 (Part 11. Division 5) of the plan that stipulates conditions to access licences which nominate water supply works approvals used to take water from alluvial sediments in the mentioned water sources	If the Mid Bega Sands was not included, licenses holders who are on an aquifer drawdown rule would also need to observe a visible flow rule and this was not the intention of the rules as discussed during targeted consultations

Public consultation is a central element of the WSP development process. In the Bega and Brogo Rivers catchment this included: more than 15 formal meetings with key stakeholder representatives, numerous focus meetings on each complex or contentious issue, four well-attended public meetings, the development and distribution of posters and digital media explaining the planning process and proposed rules and a six-week period of public exhibition.

Insights included:

- Bringing together stakeholders with vastly different and often opposing points of view (such as irrigators, environmentalists and representatives of indigenous groups) was extremely beneficial as it provided the rare opportunity for water users to listen to the concerns and priorities of 'competing' water users and to develop an appreciation for the difficulty involved in sharing scarce water supplies equitably.
- A consensus among stakeholders should not be the ultimate objective of the public consultation process as this is simply impossible in many situations. Instead, reaching a situation where stakeholders feel that their concerns have been heard and that any 'pain' they have experienced is equal to that felt by others is a significant achievement.

CASE STUDY 10. INCENTIVISING WATER REFORMS, AUSTRALIA

FIGURE A
Consumptive water use

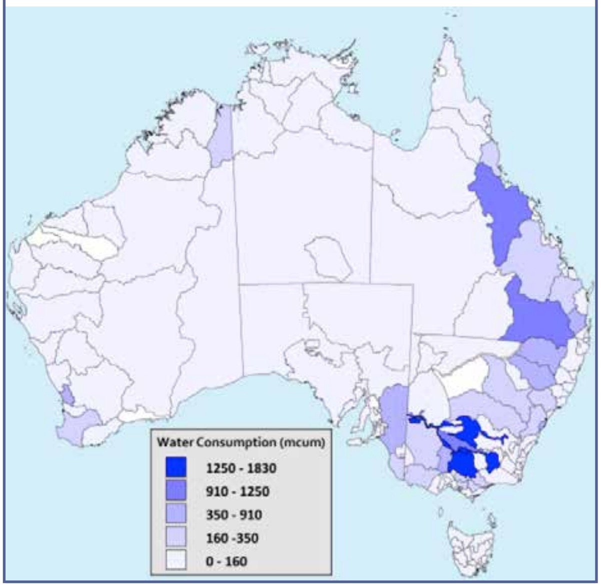
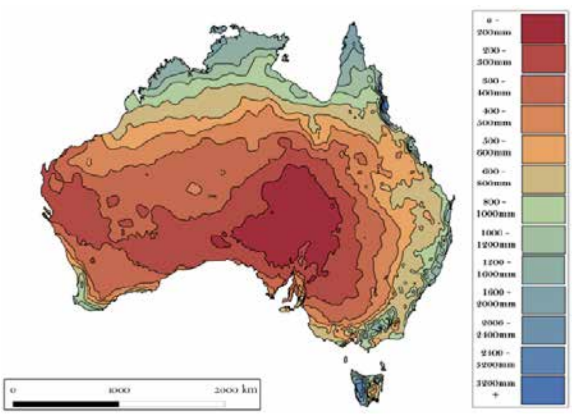


FIGURE B
Average annual rainfall 1996-2005



Australia's Constitution states that responsibility for water management lies with the six states and two territories. In the early 1990s, it was recognised that this devolution of powers by the national government was an impediment to the river basin-scale management required to tackle widespread environmental degradation and to achieve broader social, economic and political objectives in the Murray-Darling Basin. As a consequence, the national government used multi-level analysis to explore options for achieving consistent and coordinated water reforms across all states and territories. As part of the Council of Australian Governments (CoAG) mechanism, heads of state, territory and national government came together in order to negotiate the shift in power that the national government desired and the change in the way that transboundary watercourses would be governed. It became clear that the states and territories would not relinquish any of their constitutional powers over water management within their borders without adequate incentive. Hence, the 2004 National Water Initiative (NWI) included an agreement whereby states and territories would receive large financial rewards upon successfully implementing the water reforms. Experience has shown that the NWI is a model for sound water governance, for addressing the challenges of cross-jurisdictional management of shared water resources. The last biennial assessment of the NWI in 2011 concluded that it has delivered significant, tangible benefits for Australia by catalysing major improvements in water management arrangements, underpinning the speed and direction of reform, and building a broad-based commitment to common objectives. However it has yet to fully deliver its intended benefits, including the primary goals of sustainable and efficient water management. See: http://nwc.gov.au/publications/topic/assessments/ba-2011

CASE STUDY 11 ACHIEVING ENVIRONMENTAL SUSTAINABILITY IN THE MALTESE ISLANDS

The Maltese Islands are densely populated but poorly endowed with freshwater resources. During 2003-04, water accounting and auditing highlighted imbalances in water supply and the urgent need for action to be taken to ensure the environmental sustainability of Malta's fragile aquifer systems. Over-extraction from lower-coralline sea-level aquifers (effectively freshwater lenses floating on saltwater) is a particular cause for concern (see Figure 1). In recent years, an important driver has been heavy public and private investment in borehole construction (see Figure 2).

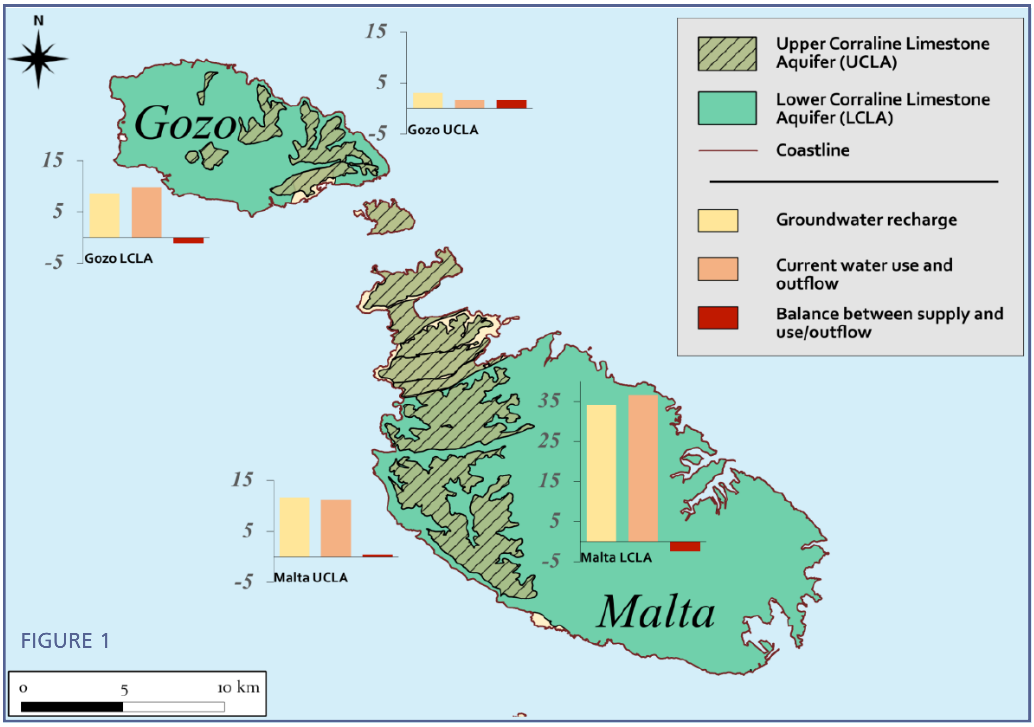


FIGURE 1

Whilst evidence that Malta's aquifer systems are under threat has been available for quite some time, political and public support for regulation of groundwater extraction has been slow to emerge. However, the 2012 Water Policy of the Maltese Islands represents a major turning point in that it lays out a raft of measures that include management of both water supply and demand and close monitoring of the status of aquifer systems. For more info see: ftp://ftp.fao.org/docrep/fao/009/a0994e/a0994e.pdf.

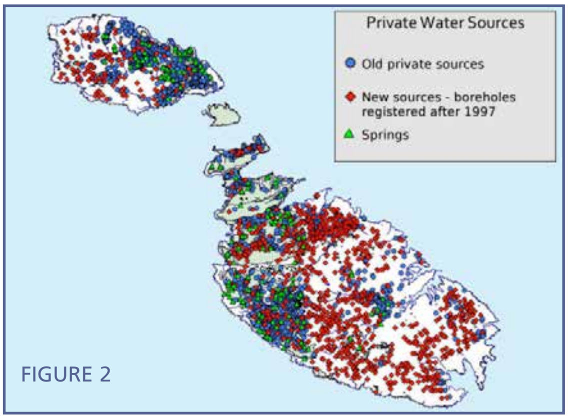


FIGURE 2

CASE STUDY 12. AUDIMOD: AUDITING THE EFFECTS OF IRRIGATION MODERNIZATIONS . APPLICATION ON RIAZA RIVER BASIN (WITHIN DUERO RIVER BASIN, SPAIN)

The AUDIMOD methodology aims at analysing, through a broad and comprehensive approach, the effects produced after the implementation of projects for the modernization of irrigation districts. The design of AUDIMOD lies on a previous work carried out through a proof of concept study on Water Tenure commissioned by FAO (2013-2014)

FIGURE A

Scheme of the elaboration of water consumption maps (combining remote sensing with other data)

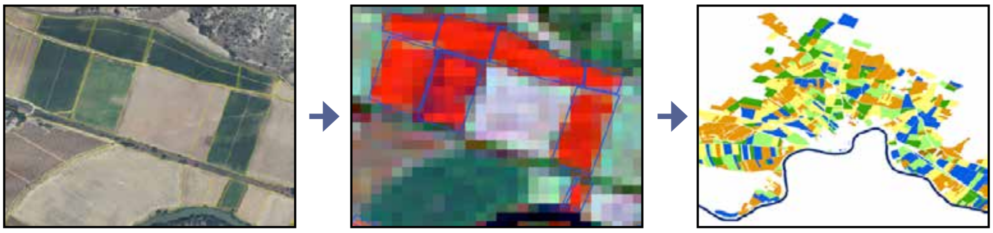


FIGURE B

Evolution of water diversion for irrigation

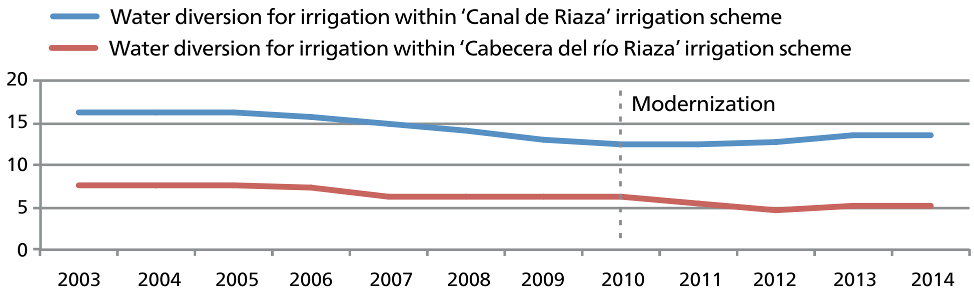
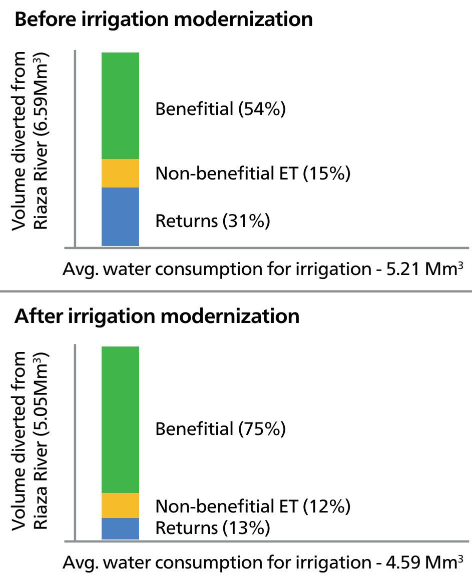


FIGURE C

Indicator on benefitial ET for Cabecera río Riaza Irrigation scheme



AUDIMOD has been tested upon an small basin with two irrigation districts diverting water from the river and which have been recently modernized (2010). This basin is strongly regulated through an artificial reservoir upstream which ensures water availability for irrigation along summer when water is naturally scarcer and higher value-added crops can be produced. AUDIMOD defines a sequential methodology with four steps: 1) Data compilation: including analysis of state of the art, field work and definition of water tenure relationships; 2) Water accounting: based on integration of remote sensing data with a wide range of other complementary data with aim to estimate how water use in agriculture has evolved before and after modernization; 3) Definition of indicators: through the construction of three key indicators which resume main agronomical, hydrological and environmental changes, and useful for benchmarking and 4) Analysis of changes [actual and potential] derived from modernization actuations, - i.e.: new scenarios of water management, changes in ecological status of water bodies and resilience to climate change of the whole system.

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Water accounting and auditing - A sourcebook

In many regions of the world, sustainable and reliable delivery of water services has become increasingly complex and problematic. Complexities that are very likely to increase, considering the unprecedented confluence of pressures linked to demographic, economic, dietary trends, and climate change. If overall demand for freshwater exceeds supply, the delivery of water services is often less about engineering and more about politics, governance, managing and protecting sources, resolving conflicts about water, ensuring rights to water are respected, and so on. Understanding and monitoring the hydrological cycle at the appropriate scale of analysis is fundamental. This is where water accounting and auditing can play a crucial role.

The rationale behind this water accounting and auditing sourcebook is that scope exists worldwide to improve water-related sectoral and inter-sectoral decision-making at local, regional and national levels. Water accounting and auditing are recommended by FAO and others as being fundamental to initiatives that aim to cope with water scarcity. This sourcebook aims to provide practical advice on the application and use of water accounting and auditing, helping users planning and implementing processes that best fit their needs.

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