Global Diagnostic
on Groundwater Governance

March , 2016

Groundwater Governance
A Global Framework for Action

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Contents

Glossary of hydrogeological terms fundamental to groundwater governance

Groundwater: Water present in the earth's crust in a saturated or non-saturated soil, weathered mantle or consolidated rock formation. Groundwater is moving in and out of these relatively 'static' geological layers — sometimes making clear cut distinctions between surface and groundwater impossible.

Aquifer: An identifiable geological formation capable of storing and transmitting water in useable quantities. The hydraulic state of the aquifer (whether confined or unconfined) determines the response of the aquifer to development. An aquifer comprises the hosting matrix of rock and the groundwater held between the matrix.

Aquifer Development: The process of pumping or exploiting groundwater in an aquifer. This can be through pumping or through control of artesian flows or aquifer discharge in seepage zones. The level of development will incur a specific aquifer response which will tend to a new equilibrium level in the long run or result in aquifer exhaustion or the limits of lifting.

Aquifer Depletion: The reduction in aquifer storage (in unconfined aquifers) or pressure (in confined aquifers) as a result of development.

Aquifer Degradation: The change in groundwater quality brought about by introduction of pollutants into an aquifer or the replacement of groundwater by lower quality water.

Aquifer Recharge: The rate at which an aquifer accepts water from meteoric sources (direct rainfall or transmission losses from stream beds) or leakage from adjacent aquifers.

Aquifer Discharge: The rate at which an aquifer drains to springs, seepage zones (including coastal sabkahs) under natural conditions.

Abstraction: Withdrawals of groundwater from an aquifer against natural flow gradients — the human development of an aquifer. The development of a spring can also be counted as an abstraction for the incremental flow that is released.

Sustainable use: A socio-economic interpretation rather than a physical one that is criteria dependant. Continued access to acceptable quality groundwater in the long term. This has to be distinguished from 'sustainable yield' or 'safe yield'.

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Preface

Whether with reference to a specific area, to a country or to the entire world — if improving groundwater governance is our ambition, then we should know our point of departure: the present state of groundwater governance and how it differs from 'ideal conditions'. The international organisations cooperating in the project *'Groundwater Governance: A Global Framework for Action'* (2011-2016) — Global Environment Fund (GEF), Food and Agriculture Organization of the United Nations (FAO), United Nations Economic, Social and Cultural Organization International Hydrological Program (UNESCO IHP), International Association of Hydrogeologists (IAH) and the World Bank — had this in mind when they designed this joint project. Consulting and analysing professional literature obviously is not enough to obtain a detailed and reliable picture of groundwater governance around the world. On the one hand, publications on groundwater governance in real life are not abundant, and those available and offering reasonable detail cover and represent together no more than tiny parts of the globe. On the other hand, the overall picture emerging from existing publications is most likely biased, because it may be expected that most water sector professionals — like other human beings — are inclined to publish more easily about progress and successes than about stagnation and failures.

The project *'Groundwater Governance: A Global Framework for Action'* therefore included a wide range of activities aiming to take stock of groundwater governance conditions and practices around the world and to enable diagnostic analysis at different spatial scales on groundwater governance. Within the realm of groundwater governance, the project's package of activities is really without precedent in terms of efforts spent, geographic and thematic scope, and the number of knowledgeable professionals involved. The activities included during the initial project phase the draft of twelve Thematic Papers, describing the state-of-the-art as perceived by selected professionals, and several Case Studies, together summarised in a Synthesis Report. Five Regional Consultation Meetings were conducted in different parts of the world, with the aim to collect as much information as possible on groundwater governance in different regions and countries, and to capture the related perceptions and opinions of the more than five hundred participants. On top of this, five regional diagnostic reports on groundwater were prepared by knowledgeable professionals from each of these regions. The present Global Diagnostic on Groundwater Governance builds on all these activities and produced outputs, in particular on the five regional diagnostics and the reports on the Consultation Meetings.

This Global Diagnostic on Groundwater Governance does not replace the large volume of Thematic Papers. Rather it intends to give a synopsis of groundwater governance in its geographic diversity and to highlight issues that are most relevant as steps are taken towards improved groundwater governance. A brief outline of the report's content follows below.

The introductory chapter calls attention to the global urgency of governing groundwater and provides an outline of the Groundwater Governance project, its main activities and outputs. In addition, it defines groundwater governance, explains the differences between groundwater policy, governance and management, and argues that governance should be tailored to groundwater separately because of a number of distinctive groundwater-specific features.

Chapter 2 presents an outline of the world's groundwater and its context — information deemed useful for proper understanding of the chapters that follow. The many aspects and interlinkages of groundwater are highlighted, as well as the large spatial diversity across the globe regarding groundwater systems, groundwater conditions and groundwater use. The chapter ends with a rationale for groundwater management and governance.

Chapter 3 describes the current status of groundwater governance around the world. To this end, first some attention is paid to a reference framework and to the region — or country — specific setting of groundwater management and governance. After that, available information on the status of groundwater governance is summarized, organised under the four main components of groundwater governance: actors, legal frameworks, policies and information/ knowledge. Mention is also made of special conditions that require unconventional management and Public intervention.

Chapter 4 deals with observed missing elements in relation to groundwater governance. This inventory is particularly useful for giving guidance to efforts intended to improve groundwater governance. Numerous deficiencies have been identified, and their relevance varies from country to country. Therefore, in this chapter (like in the preceding one), the information is presented as objectively as possible, as a true account of what has been contributed by the participants during the project's Regional Consultation meetings.

Chapter 5 focuses on how to address the missing elements in groundwater governance. It draws attention to the fact that much can be learned from positive experiences elsewhere and it presents an overview of selected identified opportunities to improve groundwater governance. These opportunities are organised again in the four categories: (i) information, knowledge and awareness; (ii) legal frameworks; (iii) policy and planning; and (iv) actors. Which ones of the identified opportunities are relevant in each particular situation and at a certain moment in time depends on the specific local context of the area concerned.

Chapter 6 presents recommended pathways toward improved groundwater governance. The first pathway consists of the adoption of relevant principles: equitable access, sustainability, transparency, participation and representation, accountability, precautionary principle, knowledge management principle and integration with water policy. The other pathways outlined deal with desirable institutional responses, promoting viable institutional strategies, anticipating climate change, anticipating the impact of technologies and of groundwater 'frontiers', and stressing the benefits of good governance.

Chapter 7, finally, presents general conclusions.

It is the sincere hope of the cooperating international organisations and of their Project Steering Committee that the Global Diagnostic on Groundwater Governance will be a source of inspiration and guidance to many organisations and individuals involved in groundwater governance and its improvement.

The Project Steering Committee
Rome, March 2016

Global Groundwater Diagnostic: Summary

1. The GEF Global Groundwater Governance Project

The groundwater challenge stems from unrestricted exploitation outside of workable governance frameworks

Groundwater development and use have proceeded rapidly in recent years, often outside of governance frameworks. As a result, unrestricted pumping and pollution have led to threats to the sustainability of aquifers, and the allocation and use of groundwater have often been poorly aligned with society's goals for equity, sustainability and efficiency. Hence, awareness has arisen in many countries of the need to improve groundwater governance.

Groundwater governance comprises a framework and set of principles that enable good management of the resource

Groundwater governance comprises the enabling framework and guiding principles for collective management of groundwater for sustainability, equity and efficiency. Although groundwater governance forms part of overall water governance, the characteristics of groundwater and the way in which it is developed and used merit specific governance provisions.

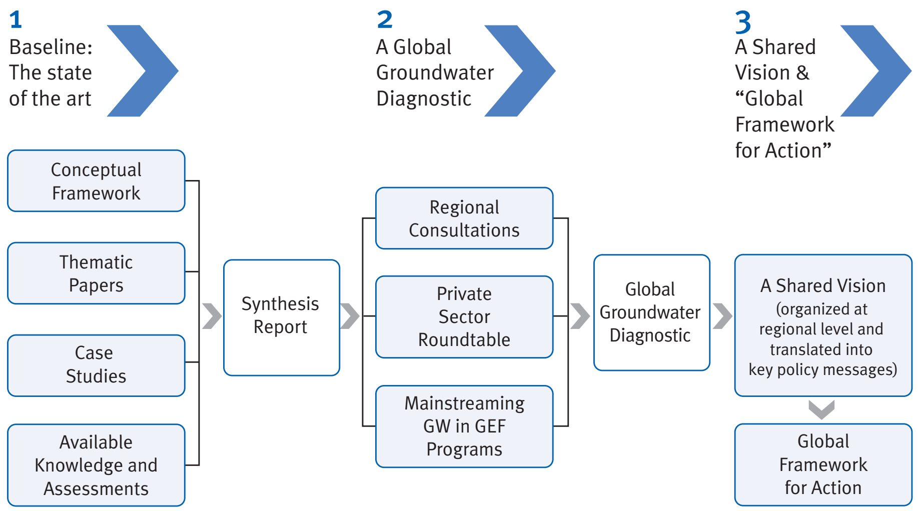
The GEF Groundwater Governance Project is designed to help countries around the world to strengthen groundwater governance

The GEF Groundwater Governance Project has been undertaken to raise awareness amongst groundwater stakeholders, lay the foundations for governance responses, and catalyse action. The GEF Project was carried out by FAO, UNESCO, the World Bank and IAH, with inputs from a large number of groundwater professionals from all continents.

This Diagnostic is a major output of the Project

The first phase of the Project (see figure below) comprised a baseline review of the science, policies and experience and a series of five regional consultations and diagnostic studies, the results of which are all consolidated in this **Global Diagnostic**. The outputs of the second phase of the Project are the **Shared Groundwater Governance Vision** and the **Global Framework for Action**.

General outline of the project: its components, activities and main outputs



2. Global groundwater and current governance

Chapter 2 of the Diagnostic presents an outline of the world's groundwater and the role of groundwater governance

The range of human activity dependent on groundwater and the aquifers that furnish it is highlighted, as well as the large spatial diversity across the globe of groundwater systems, groundwater conditions and groundwater use. The chapter concludes with a rationale for groundwater management and governance.

Groundwater may appear to be the most abundant source of fresh water, but annually recharged groundwater accounts for only 0.03% of global freshwater resources

The shallow groundwater circulating in the earth's crust continues to be the prime water source to which many poor and otherwise vulnerable people have access. But set against this apparent wealth of groundwater storage, it is the renewable groundwater that is the prime entry point for pollutants generated by human activity. The result is that shallow groundwater is under such pressure that depletion (Doll *et al*.2014) — depletion and degradation of groundwater quality (Morris *et al*. 2003) — is also ubiquitous. There are very few exploited shallow aquifers that can claim to have retained their 'pristine' character. Further, only a small portion of the deeper groundwater store can be exploited economically but still supplies significant and reliable inputs for commercial agricultural and industrial processes.

Physical and socio-economic factors affecting groundwater vary widely and governance must therefore be adapted to the local context

Groundwater conditions show large variations from country to country and between areas within countries. The ability of aquifers to store and transmit groundwater and the natural variation in groundwater quality varies with the geological heterogeneity of the Earth's crust. In combination with a diversity of climatic, socio-economic and political settings, this causes groundwater development, management and governance to be highly context-specific.

Globally groundwater supplies half of all drinking water and provides water for nearly 40% of irrigated lands

Use of abstracted groundwater produces huge benefits: groundwater supplies drinking water to about half of the world's population and irrigation water to some 40% of the world's irrigated land, and it is an essential input in many segments of the industrial sector. It plays also an important role in the development of natural energy resources (geothermal energy, oil, gas) and in the sustainability of wet ecosystems and environmental services.

Groundwater is an integral part of the hydrological cycle and needs to be managed in conjunction with linked water and land resources

Groundwater is closely interrelated with other components of the hydrological cycle, with land use, and with the use of the subsurface space and other subsurface resources. These linkages are often poorly recognized and coordination between these fields is not yet common practice.

As groundwater use has increased, challenges have emerged, particularly problems of sustainability of the resource and socio-economic problems of allocation and efficient use

Over time, the rates of groundwater abstraction have been growing steadily (driven by demography, technology and changing lifestyles), and groundwater is exposed to ever-increasing challenges. As a result, problems threatening groundwater resources and their sustainable use — including groundwater depletion, groundwater pollution and associated environmental degradation — are becoming common across the globe. In addition, in many countries there are socio-economic problems relating to distribution and equity, efficiency of use and inter-sectoral allocation.

The growing socio-economic importance of groundwater and the growing threats to its sustainability indicate that sound governance is a pressing priority

The huge value of the groundwater resources, the strong human dependence on these resources, the omnipresent threats to groundwater and existing opportunities to enhance socio-economic benefits from groundwater require groundwater resources to be governed and managed carefully. A high priority to groundwater governance will produce enormous benefits in return.

3. Current status of groundwater governance around the world

Chapter 3 summarizes the status of groundwater governance around the world. The chapter begins with a statement of the framework used in the analysis. The chapter then discusses the importance of taking into account the area-specific setting for groundwater governance, which has to reflect the issues and challenges locally present in relation to groundwater. This is followed by a discussion of general policy responses. Subsequent sections then discuss in detail the four components of governance: **actors**; **legal, regulatory and institutional frameworks**; **policies and plans**; and **information, knowledge and science**. Final sections then discuss special cases of groundwater governance, particularly the challenge of transboundary groundwater; and overall conclusions from the discussion.

Governance comprises four components: (a) actors; (b) legal, regulatory and institutional frameworks; (c) policies and (d) information, knowledge and science

The current status of groundwater governance in any country or region can be characterised by assessing its main components: **actors**, their roles and modes of interaction; **legal, regulatory and institutional frameworks**; **policies and plans** and their development and implementation; and **information, knowledge and science**.

Generally there are large governance gaps, varying according to the stage of development of groundwater and of the country as a whole, and reflecting also the specific conditions of each aquifer

Although the findings of the Project are that there are large governance gaps almost everywhere and groundwater governance is highly diverse around the world, nonetheless two common lessons have emerged. First, the state of groundwater governance depends very much on the groundwater management stage and on the economic conditions in the country concerned. Second, the focus required of groundwater governance varies with the local needs and conditions. Overall, strengthening groundwater governance is a "work-in-progress throughout the world".

Globally, there is a wide range of issues, some common, some context-specific, and groundwater governance has to adapt accordingly

Around the world there is a wide range of groundwater management issues and challenges, some of them ubiquitous (e.g. intensive groundwater abstraction, pollution), others confined to specific environments or regions (e.g. groundwater depletion, seawater intrusion, land subsidence, pollution by inadequate sanitation and wastewater treatment, pollution by industry and agriculture, inequitable allocation, inefficient use etc.). Governance has to be tailored to the locally relevant issues and challenges.

(a) Actors

People and their related institutions with direct interests in groundwater include public agencies, water consumers, and local well-owners, with governments normally having the mandate to manage groundwater

There is a *diversity of actors or potential actors* in groundwater governance, coming from the public sector, the private sector, water users, and society in general. Government agencies commonly have the mandate for groundwater management, but in practice their role may vary considerably from a top-down regulatory approach to a permissive, 'laissez-faire' position. Since so many groundwater users are operating as individuals (self-supply in urban areas or irrigation schemes) there are few if any institutions through which governance can extend. One key lever that typically remains in government hands is the set of incentive structures that can encourage uptake of groundwater pumping. Performance of public agencies varies in practice from virtually inactive to proactive and effective. In many parts of the world, low awareness of the importance of groundwater and of the issues related to it has translated into absence of political commitment, low budgets and consequent low management capacity.

Locally, well owners have typically managed their resource as individuals, but patterns of cooperation have emerged in some countries

At the local level, individual stakeholders have typically managed the resource on an individual basis, but emerging problems have stimulated the establishment of local interest groups such as groundwater management committees (Das & Burke, 2013) and specific contractual instruments to regulate the management of specific aquifers. For instance the *contrats de nappe* employed in Morocco (AFD, 2014).

There has been scant cooperation amongst stakeholders generally, but this is changing in some locations

In the majority of the countries there is no effective cooperation yet between government agencies, the private sector and other stakeholders regarding groundwater, in part because their objectives are typically at variance. However, past reluctance of government agencies to demonstrate transparency and accountability is being eroded in some countries as stakeholders begin to participate more

(b) Legal, regulatory and institutional frameworks and their application

Legal and regulatory frameworks for groundwater have often been inadequate and their application has proved problematic

In many countries, **customary law** has been applied to groundwater for generations and it is still significant — but only for small scale abstractions in rural areas of developing countries, and this has been largely overtaken by the massive scale of abstractions.

Modern legislation on groundwater — and other laws affecting groundwater — are found in almost all countries. Law typically covers ownership and use rights, protection from pollution, and institutional arrangements for management and regulation. The explosive growth of unregulated groundwater use and the resulting problems have prompted many countries to try to redefine groundwater ownership and use rights.

Responsibility for groundwater management is usually legally assigned to public agencies at the national or sub-national level, with water quality often the subject of separate legislation and assigned to a different agency. Regulatory systems typically allocate abstraction licences and control polluting behaviours.

Evidence suggests the **enforcement of laws and regulations on groundwater** is generally weak. In many countries, non-compliance is pervasive, and in all regions pollution continues largely unchecked. The problems are weak regulatory capacity and widespread lack of adherence to the objectives and practices of regulation.

The UN Draft Law on Transboundary Rights provides a framework for **transboundary aquifer management**. To date, however, only a few specific agreements on managing transboundary aquifers have been agreed.

(c) Goals, policies and plans

Groundwater governance requires clearly defined goals, policies, principles and plans

Policies set **goals** — growth, sustainability, environmental protection, equity, poverty reduction etc.; **and priorities** — allocation to urban water supply as top priority, for example. Policies also incorporate **principles** to guide planning and management, for example IWRM principles of basin management, participation, subsidiarity, incentives reflecting scarcity, and integrated inter-sectoral management, together with the precautionary principle, and the 'polluter pays' principle. Other policy choices include: **the balance between public and private roles**; and choices on the **incentive structure** — on the right balance between infrastructure, regulation or soft economic incentives like prices and subsidies. The quality and coverage of policies vary widely between countries, and policies may be proactive or — more commonly — reactive.

Resource management measures include technical interventions, generally readily accepted by local people, and non-technical measures to change stakeholder behaviour — these measures often encounter resistance.

(d) Information and knowledge

> *Information and knowledge on groundwater — and dissemination and awareness programmes — are essential for effective groundwater management*

Information, knowledge and science are critically important for management of the 'unseen' groundwater resource, far more so than for management of surface water. The required information and knowledge cover all physical and socio-economic aspects through 'snapshots' at fixed times and through monitoring to produce time series of variables.

The Diagnostic found that shallow aquifer systems are everywhere inventoried, but full mapping and assessment of larger, deeper aquifer systems have generally only been carried out in more developed countries. In only a few countries has groundwater monitoring been sustained over many years, and hence information and knowledge of the resource and its dynamics are usually limited. However, helped by information technology and global and regional projects, sharing of information and knowledge within and amongst countries has become more effective in recent years.

Information also needs to be made available in an accessible form in order to raise awareness and facilitate participation. Stakeholder awareness programmes are at different stages of advancement in a number of countries.

Location-specific conditions affecting groundwater governance

In some areas, special conditions offer additional challenges to groundwater governance

Special conditions include non-renewable or weakly renewable groundwater, off-shore groundwater reserves, transboundary aquifers, territories under occupation, emergency situations and small flat islands threatened by sea-level rise.

4. Groundwater governance – the missing elements

Chapter 4 deals with observed deficiencies or 'gaps' in relation to groundwater governance. This inventory is particularly useful for guiding efforts intended to improve groundwater governance. Numerous deficiencies have been identified, and their relevance varies from country to country.

Information and knowledge

Lack of awareness about groundwater is a pervasive problem

Lack of awareness about groundwater (including its multiple functions, opportunities and threats) is a fundamental cause of inadequate groundwater governance, because it prevents a sense of urgency from developing. This lack of awareness tends to be particularly critical in countries that show little progress in groundwater management and governance; in general, it is more prominent among decision-makers (politicians) and the general public than among government agencies in charge of groundwater management.

More specifically, the information and knowledge needed for groundwater management are most often lacking

With the exception of better off countries (most of them located in the UNECE region), few countries have invested in information and knowledge on groundwater beyond a very general and spatially aggregated level. At the level of detail relevant for groundwater management, the information is in most countries rather fragmentary and often not easily accessible, especially in Africa and in Latin America and the Caribbean. Lack of monitoring data is in most countries a major obstacle to effective groundwater management.

Legal frameworks and their application

Legal and regulatory frameworks for groundwater have often been inadequate and their application has proved problematic

Scope and comprehensiveness of domestic legislation: Although all countries have some legislation on groundwater, it is frequently scattered across several instruments and may be partial, inconsistent or out-dated. Legislation on groundwater quantity is usually separate from legislation on quality, which can be an obstacle to management. Legislation often appears 'theoretical' — poorly adapted to the realities on the ground and hard to implement. Customary rights are often ignored in legislation, which is likely to lead to problems in application — and even to negative impacts on marginalized people.

Groundwater ownership and user rights: To counter private over-exploitation of groundwater, many countries have reserved legal ownership of groundwater to the state. However, local people generally assume that they — not the state — own the groundwater, an assumption unlikely to be conducive to orderly and sustainable management.

Legal tools for transboundary aquifers: The evolving UN instruments on transboundary aquifers can serve only as guidance, and this guidance has so far been translated into only a few agreements of relatively limited application.

Goals, policies and plans

Policies on groundwater are sometimes incoherent — or even non-existent

In few countries can clear policies be found that link groundwater governance and management to well-defined societal goals of growth with equity, sustainability and efficiency. One problem is that the time horizon of politicians and decision takers is often too short — and their awareness of issues is too limited — for them to endorse the long term vision needed to manage a natural resource like groundwater.

As a result, many of the poor outcomes in groundwater are attributable to poor policies — or the absence of policies

There are many examples found in the Diagnostic of poor results from policy or the absence of policy. Early government programmes to develop groundwater for communities often failed because of lack of participation — a fault now largely corrected through more stakeholder involvement in current programmes. Programmes to help farmers reduce pumping by increasing irrigation efficiency have sometimes had the opposite effect, as farmers simply expanded the irrigated area — and increased conveyance efficiency contributed to lower groundwater recharge. Where subsidies have been used to restrict groundwater development in already over-exploited areas, this has tended to freeze existing patterns of rights and to restrict access by the poor. Permitting can be effective in groundwater regulation but in some situations this approach to regulation is ineffective — for example where agencies lack capacity to administer the system, or where society generally rejects the regulatory approach. Attempts to regulate pollution through pollution fees have not worked where the regulatory agency lacked capacity or where fees were too low to be a deterrent.

Actors

Performance of public agencies — and cooperation amongst stakeholders — on managing groundwater have been limited

Government organizations take the lead in groundwater management but their capacity and performance is variable. In many developing countries — and even some developed ones — government institutions perform poorly with fuzzy mandates, scant staff and human capacity, limited political support or institutional authority, and inadequate budgets. Fragmentation and lack of clarity on responsibilities amongst agencies is a common problem. Partly for historical reasons, agencies tend to take a top-down engineering approach, whereas the challenges of the complex socio-economy of groundwater require also a complementary bottom-up stakeholder involvement approach.

Stakeholder participation has been limited

The role of **stakeholders** has generally been limited and their approach has been remarkably passive, partly due to lack of awareness or knowledge, but mainly because the institutional structures for participation were not in place. Cooperation amongst stakeholders can be initiated through awareness programmes and through development of an inclusive organizational model favouring transparency and accountability. However moves towards such a model have so far been tentative and limited.

The performance of management agencies has been impaired by shortages of finance

Levels of financing for groundwater management are generally low, and sometimes so low as to impair activities critical to sustainable management. Agencies need to work to raise groundwater issues higher up the political agenda in order to secure commitment and financing. There is also usually scope to increase revenues from fees and from services to third parties, but this should not be to the detriment of the agency's main mission. Involving donors can boost financing in the shorter term — and can also help persuade governments of the need for governance improvements — but in the long run, agencies will have to fall back on national financing.

5. Addressing the gaps in groundwater governance

Success stories and other positive experiences can provide guidance — and inspiration

Success stories can provide guidance, but this needs to be adapted to the context and prioritized

Success stories can provide valuable lessons, although the local context and stage of groundwater development and management need to be considered in adapting these lessons. Groundwater management committees and specific contractual instruments to regulate the management of specific aquifers (the 'contrats de nappes' employed in Morocco). Such models can be adapted at scale to address aquifer depletion and degradation if more systematic governance frameworks are put in place, and that emplacement will hinge on social awareness and acceptance of the need to act.

Opportunities related to information, knowledge and awareness

The information agenda is best handled by a single agency, using modern technology — and also linking into awareness raising

Global experience shows that provision of data and information is often best accomplished by assigning responsibility for assessments and monitoring to a **single agency**. In fact, best practice examples show that **data acquisition and information management** can become more efficient and low cost thanks to modern technologies, and further efficiencies and reach can be achieved by national agencies linking in to **international programmes** that can help catalyse data acquisition, processing and interpretation. In some countries, public agencies have formed **partnerships with private businesses** such as mining companies and so brought valuable experience, knowledge and data into the public domain. A final best practice has been the use of information in **awareness** raising and lobbying efforts designed to get political and stakeholder participation and buy-in and obtain political support on key issues.

Opportunities related to legal frameworks

Legal reforms — typically focusing on water rights and regulation — have to be adapted according to their acceptability to stakeholders and to the feasibility of regulation

Legal reforms typically offer opportunities for improved governance, and these work best when they reflect the realities of the resource and the socio-economy on the ground. In many countries, there is a preference for **declaring groundwater public property**, and for backing this up with a legally enforceable **regulatory regime**. Water rights and their regulation can be a powerful instrument of groundwater management, but in many countries the approach has to be modified as there may be **limited acceptance of the approach by users** and few countries have the **capability to impose regulation and sanctions**. Regarding **transboundary aquifers,** although there are few examples of international cooperation, recently developed legal principles and guidelines illustrate pathways to cooperation.

Opportunities related to policy and planning

There have been some successes in aligning groundwater development with public policy goals and with implementing integrated approaches to management

In many countries, groundwater development has proceeded largely at the decentralized level, outside the ambit of public policy goals. Some countries have nonetheless been able to align groundwater management with policy goals like poverty reduction and environmental protection, increasing the sustainability, equity and efficiency of use and enhancing the value of groundwater to the nation. Some countries have integrated into their groundwater policies **IWRM principles** like participation, decentralization, an incentive structure reflecting water scarcity etc. and **management approaches** like conjunctive management. A few countries have been able to establishing policy and planning linkages with interrelated sectors, and some have mandated the preparation of area-specific management plans.

Opportunities related to actors

Political commitment, leadership and clear responsibilities are essential pre-conditions

Although actual experience has been patchy, it has shown that **political commitment** is essential to groundwater governance, and that lobbying for it can be accompanied by awareness-raising and by information products targeted at decision takers. Experience has also shown the importance of creating and developing **leadership** — typically setting up a lead agency — or strengthening an existing one — is a key way to improve groundwater governance and management. **Organizational reforms** can greatly improve groundwater management, especially if they clarify and consolidate mandates, empower agencies and bring management to the lowest feasible level. Increasing **private sector involvement** can strengthen governance, particularly in the sharing of knowledge and expertise and in partnerships in abstraction and pollution control.

Stakeholder involvement is essential

Perhaps the most important lesson of all is that involvement of local stakeholders is central to effective governance. Stakeholder involvement can greatly enhance the effectiveness of groundwater management, and it can be encouraged through awareness-raising, local champions, and the establishment of organizations with stakeholder participation. However, experience shows that approaches have to be adapted to the local context — and maybe also combined with other solutions.

Empowered, resourced and accountable public agencies are key

Effective agencies are key to implementation, and here determinants of success include capacity building, financing — core funding, perhaps supplemented by cost recovery — and the need for accountability and transparency, which experience shows are essential to the emergence of necessary cooperation and trust. Finally, **partnerships with international organisations** offer significant opportunities to enhance groundwater governance.

6. Recommended pathways towards improved groundwater governance

Principles for governance of groundwater

Commonly accepted water governance principles apply — but also the 'precautionary principle' and the 'knowledge management principle'

Variable outcomes and missed opportunities in groundwater management underline the shortcomings of groundwater governance and some requirements in addition to the governance of surface water — but also the need for integrated management of the whole hydrological cycle. Thus commonly-accepted water governance principles — equitable access, sustainability, accountability, transparency, participation and representation, accountability, integration with overall water resources management — all apply, but they need to be adapted to the specific character of groundwater and to be supplemented by two principles of special relevance to groundwater: the precautionary principle - protecting aquifer water quality and assuring recharge — and a knowledge management principle.

Getting started – structuring an approach to strengthened groundwater governance

Strengthening groundwater governance can start with straightforward preliminary steps — but the governance system intended has to reflect the realities on the ground

Although governance arrangements will vary enormously according to local conditions and constraints, the components of a governance response to groundwater management challenges are clear: a working system of arrangements — actors, legal frameworks, policies, information - that serve a public interest. Several steps to setting up a practical governance framework can be suggested — pulling together information to **establish stakeholders' interests**, identifying a **lead agency**, defining rights and incentives, and ensuring **transparency and accountability.** Governance — and management — need to be **realistic**, based on understanding of both hydrogeology and socio-economy — as well as of political realities.

Actors

A dedicated management agency with a clear mandate and capacity is the preferred option

Assigning **clear responsibility for groundwater management** is important — dedicated groundwater management agencies with access to good information and knowledge are the best approach, but many locally-evolved variants are possible. Key factors in success are: clear mandate; adequate staff and capacity for the functions assigned; adequate sources of core financing; and political and stakeholder support.

Legal framework

Rights and regulatory regimes can vary from 'top down' to highly participatory — but they all have to be workable in the local context

Deciding on water rights and the feasibility and desirability of regulation: Approaches to rights vary with the context, from private rights to centrally controlled public rights. In many cases, rights have already been appropriated by well owners, and these rights have to be taken into account in any attempt to define rights legally. Similarly with regulation, effective regulation can be done by a strong government or by local stakeholders, with many variants in between. Approaches to regulating groundwater have proved highly problematic and have often not reached their objective — thus judging how to regulate groundwater use and determining precisely where to start needs to be carefully thought through.

Planning and management

Planning and management are best done at the lowest possible level and through participatory approaches

Deciding on the appropriate scale of planning and management: The best planning and management unit may be the local level where interests and problems can be identified and responses can be agreed and applied – although even here there may be conflicts between, say, local agricultural use and transfer to meet municipal needs. Management rules at the local level can be simple – for example, agreeing acceptable drawdown levels between groups of aquifer users. Experience suggests that stakeholder engagement from the outset is vital, and that institutional structures should be participatory.

Quantitative and qualitative objectives need to be set

Defining mutually acceptable levels of depletion and degradation: Once a manageable unit has been identified and the procedures for stakeholder involvement are working, it should be possible to agree on objectives and to work towards them — although approaches, objectives and management changes will vary considerably between locations. One thing that should be clear to all stakeholders from the outset is that anticipating the evolution of groundwater quality is very difficult as quality deterioration is a slow process and responsibility is difficult to attribute.

Plans should reflect how costs and benefits are to be shared

An important part of planning and management will be analysing the costs and benefits of groundwater management action — such as depletion or inter-sectoral transfer — in **economic** terms, taking account of opportunity costs, externalities etc. This analysis will drive decisions on investment and management, and will need to be done in a transparent way, open to question by all stakeholders.

...and plans, particularly for non-renewable groundwater, need to provide for what to do when access to groundwater disappears

One outcome that needs to be considered well in advance — and transparently - in planning and management is what to do when access to groundwater disappears. Exhaustion of aquifers can lead to out-migration from rural areas or entail high costs in water transfers from other sources — and these impacts and related costs should be evaluated in advance when management decisions can still affect outcomes

Information

Information will be crucial to management

A necessary — but not sufficient — condition of groundwater governance is that information has to be accessible and useable by those who have a direct impact on groundwater quantity and quality. It is a truism that ‘you cannot manage what you cannot measure’, and this is especially true for groundwater, the ‘hidden resource’.

Climate change and groundwater

Groundwater will be an invaluable buffer as climate becomes more uncertain

Changes in rainfall and run-off patterns are unpredictable and vary by location — but groundwater will be a key element in building resilience, buffering the annual and seasonal variations in rainfall and runoff.

Climate change will also affect groundwater quantity and quality

Climate change is likely to affect the hydrological cycle and aquifer circulation, land use, and patterns of recharge and pollution. Changes in patterns of land use associated with climate change — for example, forest clearance — will also affect recharge.

Designing governance to cope with the impact of new technologies and emerging groundwater issues

Information systems need to take advantage of advances in geophysical knowledge and feed into improved management

Groundwater science and technology is relatively new, and advances are constant. Groundwater governance and management therefore have to take these advances into account. One area of advance is in **geophysical knowledge** — scientific advances are creating the potential to acquire much better hydrogeological information. It is essential that this be captured and fed into improved groundwater management decisions. This will require capable, well-resourced information systems, a planning and management capability, and a governance system capable of delivering results on the ground.

Planning and regulation need to keep pace with new technology for exploiting groundwater

Drilling technology and the efficiency of **pumping equipment** are constantly improving. This will make groundwater abstraction easier and cheaper. The challenge of effective regulation will become greater, strengthening the case for the introduction of collaborative or self-regulating regimes.

New issues are emerging, particularly in urban areas and sub-surface exploitation, which groundwater governance will have to deal with

Groundwater governance will have to deal with further impacts in urban areas and services. Issues of aquifer management for urban areas are likely to intensify, including geo-technical stability, quality management in the hinterland, and the use of exhausted peri-urban aquifers as waste dumps. Issues regarding interference with aquifers from other sub-surface activities are likely to become more pressing. The issue of the potential impact of sequestering carbon in aquifers is also now being raised.

Designing governance to optimize benefits of groundwater — and to manage the risks

Livelihoods outcomes

Governance needs to ensure equitable sharing of benefits from groundwater

Equity and welfare benefits from groundwater can be considerable — but they need to be protected under governance arrangements. Already in many locations, there is highly skewed access to groundwater, with impacts of impoverishment and marginalization for those excluded. Governance arrangements have to ensure that public policy goals of equity, sustainability and efficiency are pursued.

Markets in groundwater

Where there is potential for water markets, governance provisions need careful thought

Groundwater markets have emerged in several countries but their generalization is limited by inherent challenges — defining water rights, establishing a regulatory framework, accounting for resource costs and externalities. Where purely private, unregulated markets develop, the outcomes are likely to be inequitable and inefficient.

Macro-economic outcomes and setting the incentive structure

Two key policies need careful design — the incentive structure for all types of groundwater exploitation, and the approach to the 'mining' of non-renewable groundwater

Governments have a major stake in ensuring that groundwater is developed and used for the common good. One key element here is the **incentive structure,** which is typically controlled by government to a large extent and which can be used to improve efficiency and sustainability. One key reflection for governments is to decide on **whether and when non-renewable groundwater should be drawn down**. This will require a policy decision based on economic assessments which recognize both the benefit of current abstractions for production or water supply and the value of leaving water in the ground either to maintain quality, aquifer health and ecosystem services or for the benefit of future generations.

Environmental outcomes

Factoring in impacts on the environment to groundwater policy is challenging — but essential

Another public interest area on which governments need to formulate policy is the environment. The range of environmental externalities of groundwater is wide and the extent to which they should be assessed and any needed remedial action taken will depend on capacity to monitor and on the costs and feasibility of assessment and remediation.

7. Conclusions and recommendations

Governance is essential

Poor governance has led to multiple problems in groundwater

Groundwater is an extremely important resource for humankind and ecosystems. However, it has been developed in many locations outside of a coherent governance framework and this has contributed to current problems of depletion, pollution and inequitable and inefficient allocation. Stronger groundwater governance is needed to manage the resource and control or mitigate problems. For the most part the act of groundwater exploitation does not throw up management practices, infrastructure and institutions that are governable. The point at which consuming behaviour is expressed in a market (such as the purchase of food) the behaviour is generally ‘governable’ and trading standards, food safety, measures and value become widely applicable. Surface water exploitation tends to reveal such types of things quickly to the extent that it usually requires visible structures and institutional arrangements (water utilities) that are governable. With the exception of municipal well fields with well-organized and marked recharge and/or pollution protection areas, the bulk of groundwater exploitation remains hidden from such public scrutiny.

The challenges are considerable

In many locations, there is no coherent current governance framework, and where there is a framework, this Diagnostic has often found it to be frail. Knowledge and understanding of groundwater amongst stakeholders is limited and this is reflected in decisions and behaviour. The range of physical, socio-economic and political settings to which groundwater governance has to be adapted is very wide, so that there is no one solution.

There are, nonetheless, examples of good groundwater governance

Examples of good groundwater governance can be observed in many parts of the world, and a diversity of useful approaches to governance and management have been developed that may be replicated in other areas, provided that the area-specific context is taken into account.

This diagnostic has identified pathways to improvement

Following these pathways can help put in place more practical governance arrangements that facilitate aquifer management in pursuit of societal goals. Some groundwater opportunities have been foreclosed through neglect, but even if simple sustainability is not achievable, responsible, conjunctive management in line with socio-economic and political realities could open up new opportunities. Although it is likely that governance arrangements to maintain aquifer quality may prove more challenging than just managing quantity, there are still options available.

The two most important lessons from the Diagnostic are: that stakeholders at the local level have to be part of the solution; and that governance arrangements have to reflect the reality on the ground

One theme throughout the findings of the diagnostic has been the common failure to grasp the central importance of the human dimension — human goals, incentives, rights, practices and constraints — and the consequent neglect of the **central role of stakeholders and collective management solutions at the local level**. Groundwater governance has to recognize that users at the local level are the key to good management, and measures have to recognize users' priorities and align incentives for change with these priorities. In fact, just as governance principles and recommended approaches to applying them can guide management at the local level, so lessons from the local level can be learned, and the overall governance framework can then be adjusted in the light of this 'bottom up' reality. These approaches to collective governance arrangements are typically easier to implement in rural areas than in and around towns, but the role of local stakeholder involvement is key in virtually all settings.

Other key factors found to particularly affect governance are awareness, leadership and agency empowerment

Ignorance about the importance, nature and challenges of groundwater was found to be pervasive, from top decision makers down to users at the local level. This lack of awareness has driven lack of interest in putting in place and adhering to the governance frameworks needed to properly manage the resource in pursuit of societal goals of equity, sustainability and efficiency. Linked to this has been a pervasive absence of leadership by mandated agencies. Typically, agencies responsible for groundwater have been lacking in the authority, capacity and financial resources needed to take the lead in efficient management in line with policy and plans.

Four key recommendations on how to apply these lessons in practice emerge from this Diagnostic:

- Emphasize simplicity and the communication of action-oriented messages
- Recognize that actual management is done by and with stakeholders on the ground — and work back to adjust the overall governance framework accordingly
- Account for the benefits and costs of groundwater development, and use the results to convince decision-takers of the need for reform
- Good groundwater managers need to be innovative technically – but also equally proactive in seeking partnerships with key stakeholders — farmers, industry, municipalities etc. — and in investing in strong organizational capacity

Next steps: the Global Vision and the Framework for Action

The priorities for improving governance are thus: **stakeholder involvement** — awareness, communications, structures for cooperation and collective action; **knowledge generation and sharing**; **capable managing agencies**; a **legal and regulatory framework adapted to the realities** on the ground; **integrated water resource management approaches**; and **inter-sectoral cooperation and public-private partnerships**. In addition, **mobilizing high level political support for improved groundwater governance** is a further imperative.

These priorities are summarized in the Global Vision and developed into guidelines for action in the GEF Framework for Action. As has been emphasized throughout the Diagnostic, putting all this into practice requires adaptation to local specifics, setting of realistic goals, and mobilizing political support — and involving stakeholders from start to finish.

1. Introduction

"Common pool resources like groundwater may require specific governance arrangements if the objectives of sustainability, efficiency and equity are to be attained."

(Braune and Adams, 2013)

1.1 The GEF Global Groundwater Governance project

Unrestricted pumping and uncontrolled waste disposal and use of agricultural chemicals have led to threats to the sustainability of aquifers — and hence to awareness of the need to change

Open access to groundwater and unconstrained pumping of groundwater and uncontrolled waste disposal to the aquifers has characterized groundwater development until the mid-twentieth century. The systems of behavior governing its abstraction and use have been individual and private (through self-supply) until the consequences have triggered collective action to regulate use and protect aquifers. More recently, demographic pressures, economic and technological development and other factors have triggered unprecedented changes in the state of our groundwater systems, resulting in a growing awareness of the limits and vulnerability of this critical resource.

As a result, governments have developed locally-adapted approaches to try to recover control over groundwater

In response to this new awareness, groundwater resources management (or groundwater management) has been embraced and developed in most countries. Usually initiated by governments, it pursues the controlled exploitation and adequate protection of groundwater to achieve broad society goals. Groundwater resources management comes in many forms and needs to be tailor-made to local conditions. It is action-oriented and uses technical instruments, legal and regulatory instruments, and incentives/disincentives to achieve its goals.

The technical characteristics of groundwater and the need to associate stakeholders in management drive the need for special governance arrangements for groundwater

While groundwater management is an inseparable part of overall water resources management, it deserves special attention due to the hidden, invisible nature of the resource, its high stock-to-flow ratio and the relatively dominant role of encouraging changes in human behavior as a tactic for achieving management goals. The common resource characteristics of groundwater, the close interaction between groundwater and land use are additional challenges compounded with the often limited understanding among policy makers of the geological processes that control groundwater circulation and aquifer state.

Nevertheless, problems of resource degradation persist – as do lost opportunities for more efficient and sustainable use

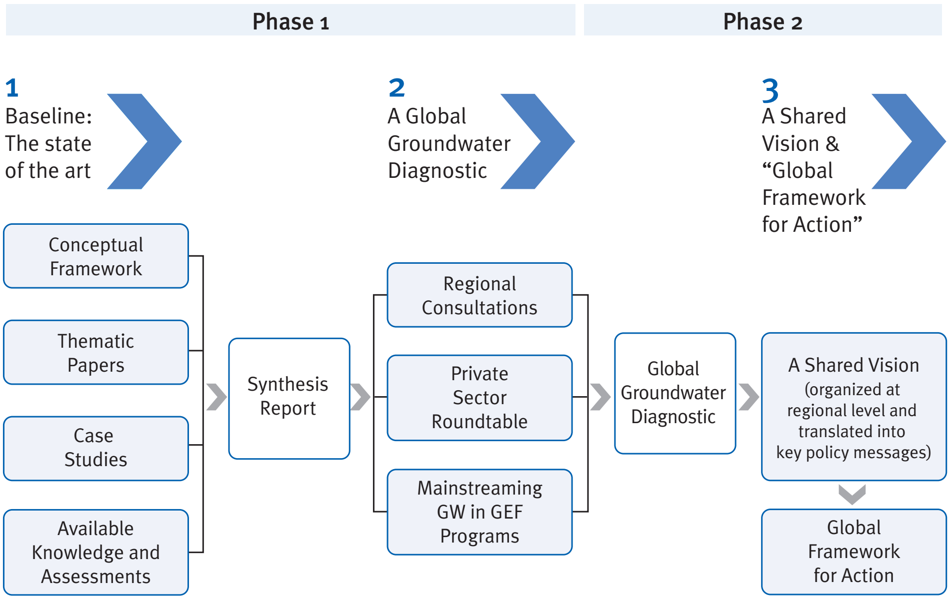
In spite of the efforts being made across the globe to introduce some degree of management to the use of this resource, groundwater exploitation is far from sustainable. Groundwater resources are being rapidly degraded in terms of quality and quantity, while opportunities that currently exist for the strategic expansion of groundwater use are being compromised, or simply remain unknown to potential users. Effective management is often hampered by poor coordination and co-operation between relevant actors and/or by a lack of capable institutions and instruments to align stakeholder behavior with policy objectives.

Groundwater governance — enabling frameworks and guiding principles — could help steer groundwater management towards societal gals of equitable, efficient and sustainable development and use

In view of this alarming situation, the concept of groundwater governance has emerged, but only recently. Groundwater governance provides “overarching frameworks and guiding principles that enable the sustainable management of groundwater resources and the use of aquifers”. Enabling frameworks and guiding principles would be directed towards the achievement of groundwater resources management goals such as resource sustainability, water security, economic development, equitable access to benefits from water and conservation of ecosystems. Unfortunately, groundwater governance is inadequate in most countries, thus needs to be strengthened.

Figure 1.1

General outline of the project, its phases and its components



The GEF Groundwater Governance Project has been undertaken to raise awareness amongst groundwater stakeholders, lay the foundations for governance responses, and catalyze action

It is for these reasons that the Global Environmental Facility (GEF) has joined forces with the Food and Agricultural Organisation of the United Nations (FAO), UNESCO's International Hydrological Programme (UNESCO-IHP), the International Association of Hydrogeologists (IAH), the World Bank, and a multitude of scientists and water managers from across the globe, in the project *'Groundwater Governance – A Global Framework for Action'*. This project — in the remainder of this report briefly referred to as the *Groundwater Governance Project* — represents an ambitious effort to raise global awareness on the urgent need for improved groundwater governance, lay the foundations for a global response to this new challenge, and catalyze the necessary action. Figure 1.1 presents a general outline of the project, its phase and its components.

*The first phase of the Project comprised a baseline review of the science, policies and experience and a series of consultations, the results of which are all consolidated in this **Global Diagnostic***

The first phase of the project — now completed — consisted of a global review of groundwater issues with focus on governance and was developed along two lines of action. The first line of action was a baseline review in which the project evaluated the state of the art on relevant aspects of groundwater science and technology, as well as the state of existing policy frameworks and lessons learned. The outcomes of this baseline review are presented in a series of thematic papers and country case studies and summarized in a Synthesis Paper.[1] The second line of action included five regional expert and stakeholder consultation meetings (Table 1.1), organized in order to obtain a reliable global picture of groundwater management and governance challenges and practices. The present Global Groundwater Diagnostic, the final product of the First Phase, integrates the regional and country experiences, the perceived needs and the prospects for the future.[2]

1 These thematic papers provide a rich resource containing more detailed background material on the governance of groundwater for the interested reader and are available from the Groundwater Governance Project website

2 The underlying Thematic Papers, Case Study Reports, Synthesis Paper, Reports on the Regional Consultations and Regional Diagnostic Reports are all included in the list of references

The outputs of the second phase of the Project are the ***Shared Groundwater Governance*** *Vision and the* ***Global Framework for Action***

Moving from the Global Diagnostic and the consolidated knowledge achieved during Phase 1, the second phase of the project developed — through expert work and global consultations — two main outputs. The first one is a globally valid and forward looking **Shared Groundwater Governance Vision** focusing on resource sustainability, water security, economic development, equitable access to benefits from water and conservation of ecosystems, that would support and strengthen the MDGs and the SDGs that are presently being formulated. The second main output is the **Global Framework for Action**, consisting of overarching generic frameworks, guiding groundwater management principles and best practices that would enable the sustainable management of groundwater resources, in other words: the achievement of the Vision. It also includes recommendations for concrete actions and project partner commitments.

1.2 Regional and Global Diagnostics on Groundwater Governance

The present document — the ***Global Diagnostic*** *— builds on five regional consultative meetings and on* ***Regional Diagnostics***

Regional Diagnostics have been prepared for the same five regions (see Figure 1.2) for which the project organized a series of Regional Consultation Meetings during 2012 and 2013. Table 1.1 summarizes key data on these meetings and the related regional diagnostic reports. The regional meetings were attended by 80 – 120 experts each and have been very successful in bringing together up-to-date information and opinions on groundwater and its governance and management in the regions concerned.

The ***Diagnostics*** *also drew on a wealth of other sources*

The reports on the regional consultation meetings have been a helpful point of departure for the authors of the regional diagnostics, but these used in their analysis much more information, either generated by the project or from external sources. In a similar way, the **Global Diagnostic** — the subject of this report — is to a large extent based on the **Regional Diagnostics**, but draws also on other relevant information sources, both produced by the project (as mentioned already) and externally.

Figure 1.2

The Earth's subdivision into regions as adopted by the Groundwater Governance project

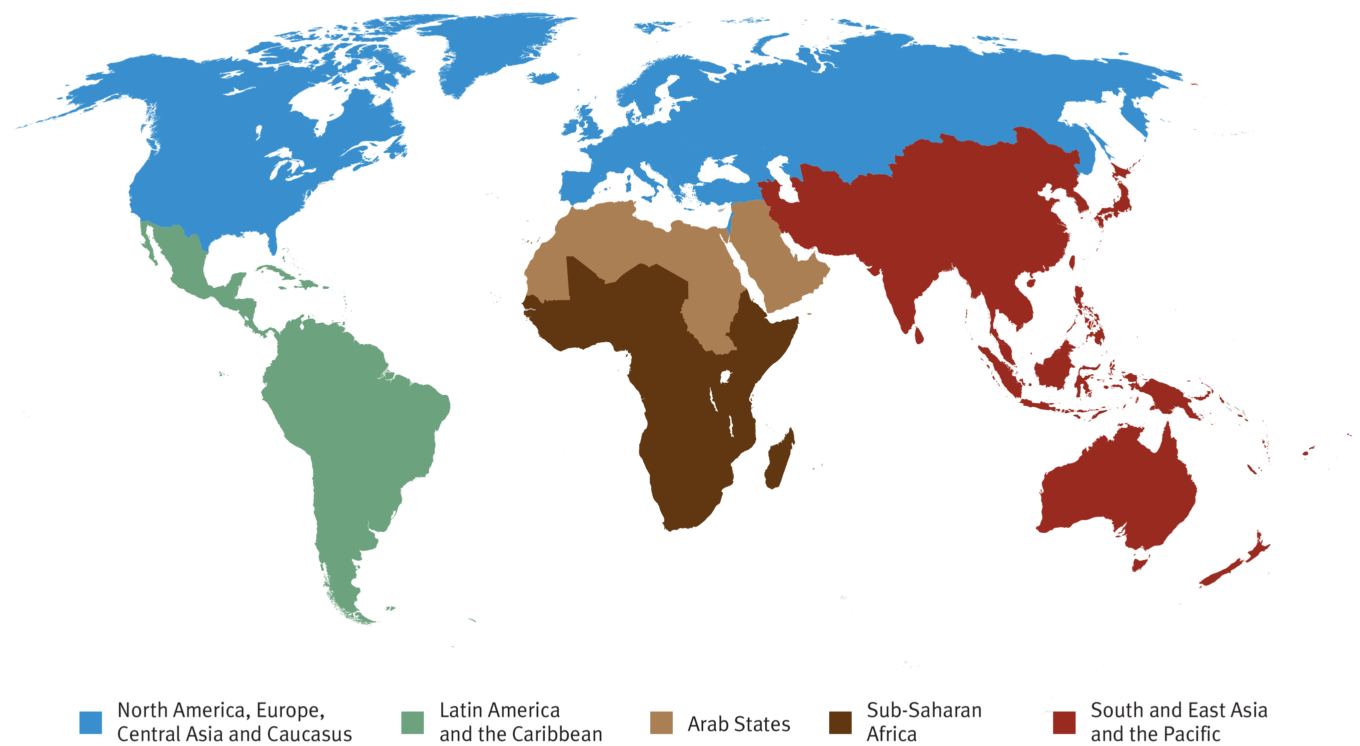


Table 1.1

Key data on the Regional Consultation Meetings and Regional Diagnostics

Region	Regional Consultations		Regional Diagnostics	
	Location	Timing	Author(s)	Latest draft
Latin America and the Caribbean (LAC)	Montevideo, Uruguay	18-20 April 2012	Ofelia Tujchneider	July 2013
Sub-Saharan African Region	Nairobi, Kenya	29-31 May 2012	Eberhard Braune, Shafick Adams	August 2013
Asia and the Pacific	Shijiazhuang, China	3-5 Dec. 2012	Yatsuka Kataoka, Binaya Shivakoti	August 2013
Arab Region	Amman, Jordan	8-12 Oct. 2012	Waleed Al-Zubari	August 2013
UNECE Region	The Hague, The Netherlands	19-21 March 2013	John Chilton, Ebel Smidt	November 2013

1.3 Defining and understanding groundwater governance

Groundwater governance comprises the enabling framework and guiding principles for collective management of groundwater for sustainability, equity and efficiency

The human use of groundwater and aquifers is presently governed by a mix of social customs, codes, laws and regulations. Achieving a state of 'good' groundwater governance is a relatively complex concept and therefore there is considerable variation among the definitions of groundwater governance presented by different authors. Here we adopt a slightly modified version of the definition by Foster and Garduño (2013), which reads as follows:

"Groundwater governance comprises the enabling framework and guiding principles for responsible collective action to ensure control, protection and socially-sustainable utilisation of groundwater resources for the benefit of humankind and dependent ecosystems."

Definitions of groundwater governance have been discussed in different reports of the Groundwater Governance project, e.g. in the Synthesis Paper and in some of the Thematic Papers. Box 1.1 elaborates on the distinction between groundwater governance and groundwater management. This definition of governance highlights the four components of governance — **actors**; **legal and institutional framework**; **information, knowledge and science**; and **policies and plans**. This definition into four components is fundamental to the organization of this Diagnostic, in particular to the assessment of status, gaps and opportunities in Chapters 3-5.

Box 1.1

Groundwater governance and groundwater management?

Groundwater governance comprises the enabling framework that establishes **who** formulates policies and strategies and is responsible for their execution (**the actors**) and **how** different stakeholders interact (**the legal and institutional framework**). Decisions made by the actors regarding what to do in pursuit of societal goals are driven by **information, knowledge and science**, and result in **policies and plans** which define **why** activities are needed and **when** they should be undertaken or completed. This framework determines the management of groundwater resources and the use of aquifers.

Groundwater management is **what** the actors do within the governance framework; activities related to the development and protection of groundwater to implement the policies and plans which have been established. The hydrogeological conditions and distribution of human activities will determine **where** these management activities are required.

Adapted from Chilton and Smidt (2013), as modified from Varady (2013)

Although groundwater governance forms part of overall water governance, its characteristics and the way in which it is developed and used merit specific governance provisions

Just as groundwater resources are part of water resources in general, so is groundwater governance part of water governance. Nevertheless, there are several reasons for paying attention to groundwater separately (without ignoring its interaction with other components of the hydrological cycle):

- Groundwater is present below ground, hidden from the eye, in the vast subsurface domain and down to considerable depths. Its interactions with the geological formations and with human activities in the subsurface are very different in nature from the interactions of surface water with its environment at the surface.

- Groundwater represents almost 99% of all freshwater volume stored on Earth and is therefore a unique large freshwater reserve that can act as a buffer during extended dry periods.
- The time scales of groundwater processes are much longer than those for surface water and atmospheric water. It takes a long time for reserves to build up, and a long time to recover from any deteriorated state.
- Its omnipresence makes groundwater accessible to almost anybody and vulnerable to nearly any human polluting activity. Consequently, groundwater management depends far more than surface water on influencing the behavior of people.
- The subsurface environment itself, including the aquifers which contain groundwater, has a number of other uses which may require specific governance approaches.

These and other considerations (see also Chapter 2) show how different groundwater and its context is from surface water. These differences call for dedicated approaches to groundwater governance that are rather distinct from the approaches in surface water governance.

2. Global groundwater and its context in relation to current governance

"Aquifer data and information are a basic requirement for good governance; such information must be set out in a simple and user-friendly manner to permit effective participation"

(Chacon & Bushell in Da Franca, 2012)

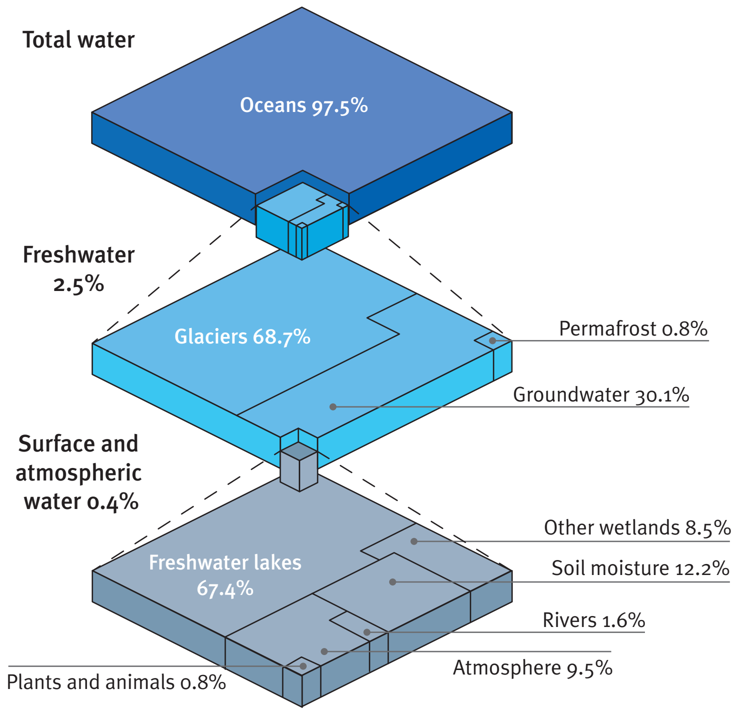
2.1 The significance of groundwater in global water resources availability

Groundwater may account for 99% of the globe's liquid fresh water, but only 0.03% of the global freshwater store is made up of annually recharged groundwater

According to the most recent estimates compiled by Shiklomanov and Rodda (2003), the total volume of water in the Earth's hydrosphere is 1,386 million km^3. Only 2.53% of this volume (35.03 million km^3) is freshwater, virtually all of which can be found on the landmasses that cover 29% of the surface of the globe. A breakdown of this freshwater volume shows that almost 68% of it corresponds to glaciers and permanent snow cover, and 30% to fresh groundwater.

Figure 2.1

Global break-down of the world's water



(WWAP, 2006)

The estimated volume of fresh groundwater is 10.53 million km³, which is almost 99% of all liquid freshwater on Earth. The combined volume of freshwater present in lakes (91 thousand km³), swamps (12 thousand km³), streams (2.1 thousand km³) and the atmosphere (13 thousand km³) thus is two orders of magnitude smaller (see Figure 2.1).

> *Groundwater stays in aquifers for very long periods — 900 years on average — so represents a precious water capital — a strategic reserve and buffer against shocks*

Fluxes of water exchanged between the different compartments of the hydrosphere are another important dimension of freshwater quantity. They reveal the shares of the different components of complex hydrological systems (or even the global hydrosphere) in the circulation of water in the hydrological cycle. The total global groundwater flux (calculated as the long-term average of groundwater recharge and discharge) is estimated to be around 12,000 km^3, which is significantly less than the total global surface water flux (around 42,000 km^3) and only a minor fraction of the global flux of atmospheric water.

The ratio of stored volume over mean flux defines the mean period of renewal or mean residence time (slightly hypothetical, because assuming long-term stationary conditions). From the numbers mentioned above follows a globally mean residence time for groundwater of almost 900 years, but variations between individual groundwater systems are very large, due to differences in size and hydro-climatological conditions. This is much longer than the globally mean residence times of water in lakes (17 years), bogs (5 years), soil moisture (1 year), river systems (16 days) and atmospheric moisture (8 days), which makes groundwater the world's freshwater buffer *par excellence*.

Groundwater and surface water constantly interact and so need to be assessed and managed conjunctively

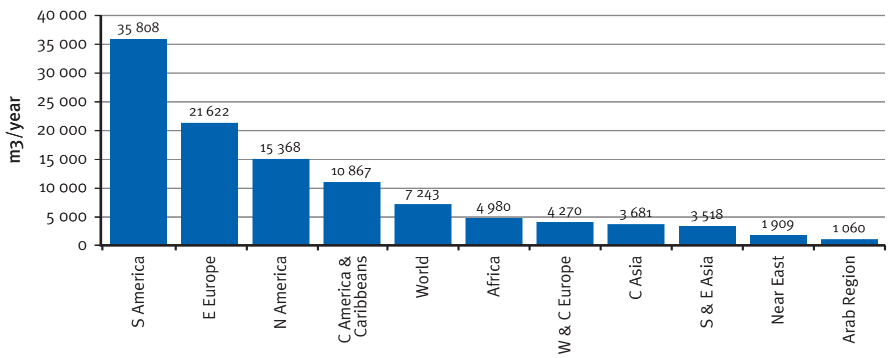
In most areas, the lion's share of the groundwater flux is shared with surface water systems, mostly because of groundwater discharge contributing to the base flow of streams. This 'overlap' corresponds on average to 89% of the groundwater flux and should not be overlooked when assessing the total 'blue water' resources, i.e. surface water and groundwater combined. Furthermore, it should be taken into account that exploitable freshwater resources tend to be significantly less than the freshwater flux, due to a number of practical constraints, e.g. great depth of certain groundwater occurrences or very irregular distribution in time of surface water flows.

Groundwater distribution is highly variable and bears little relation to population distribution, so that per capita availability is highly uneven

The distribution of freshwater around the world is highly variable, and population density is not proportional to its availability. Figure 2.2 shows the huge contrast between regions with abundant freshwater resources and those where the freshwater resources are scarce.

Figure 2.2

Per capita renewable freshwater availability in different regions of the world



(WWC, 2006)

2.2 The nature of groundwater occurrences

Groundwater is stored in and moves through 'aquifers'

Groundwater is present and moves in the Earth's crust, in particular in its shallow part and with preference for subsurface units where the interstices (pores, fissures, etc.) within the rock mass are relatively favorable for the storage and movement of groundwater. Such subsurface units — reservoirs and at the same time 'highways' for groundwater movement — are called *aquifers*.

Aquifers are of many different kinds, with shallow aquifers being fast moving and readily exploited, and deep aquifers generally slow moving with large, long term reserves

There is an enormous diversity of aquifers around the world and their exposure to the global hydrological cycle determines the groundwater occurrences than can be used. Key factors underlying this diversity are the lithology of the solid aquifer matrix and the hydraulic interaction with surface water and the atmosphere. Sand and gravel, sandstone, karstic limestone and volcanic rock form the solid matrix of the majority of the most productive aquifers in the world. The different types of aquifer rock each have their specific characteristics

from the point of view of storage, flow and water quality. They also present markedly different conditions for the exploration and exploitation of groundwater. **Shallow aquifers** in humid climates usually are actively recharged and accommodate a dynamic subsurface branch of the hydrological cycle. Groundwater passing through shallow aquifers in dry climates is less prolific because groundwater recharge may be intermittent. **Deep aquifers**, especially those covered by thick impermeable strata (like clays), tend to have a very limited or indirect hydraulic contact with water at the surface and receive substantially less recharge.
Hence, groundwater in deep aquifers moves usually very slowly and has a comparatively long mean residence time and acquires the mineral character and temperature of the host rock.

37 mega aquifers contain two thirds of stored groundwater, but it is shallow aquifers that receive most recharge

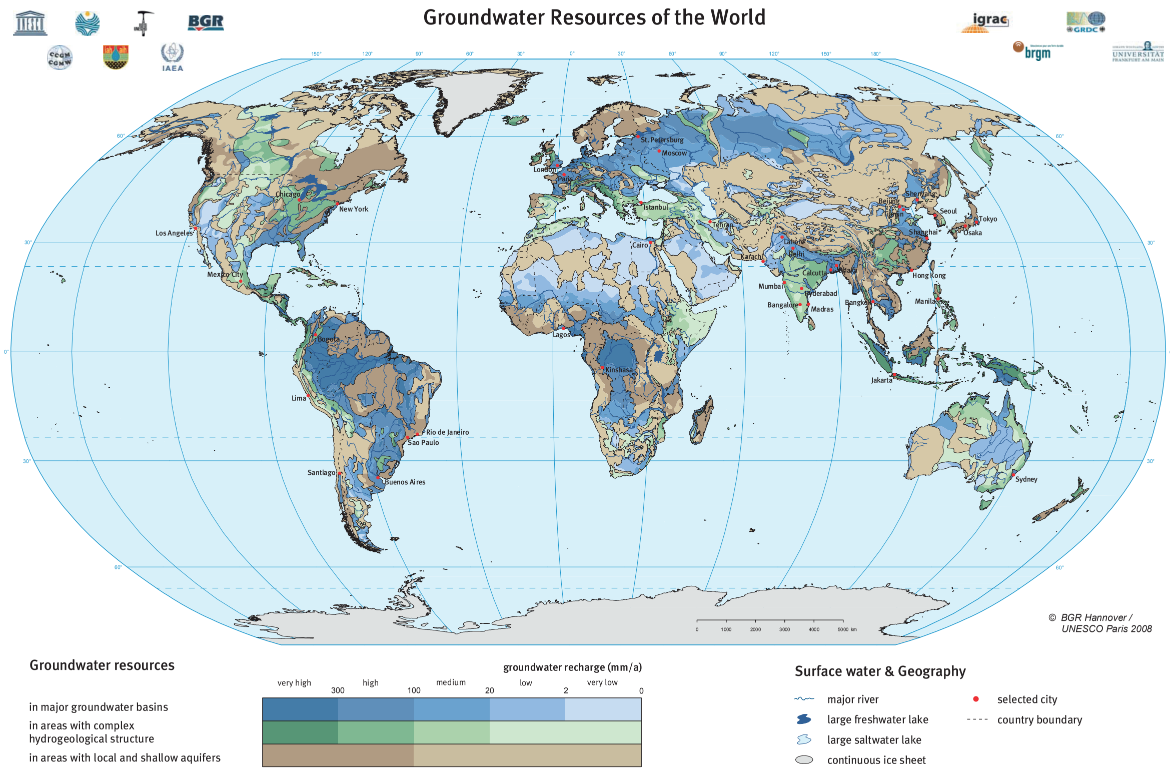
The world's 37 mega aquifers as delineated by Margat (Margat and Van der Gun, 2013) cover together 26% of the global land mass (excluding Antarctica) and contain approximately two-thirds of the global groundwater volume stored, but receive no more than 10% of the global groundwater recharge. This shows that they are very important in terms of volumetric reserves (buffers) even if not coupled to the current water cycle. The numerous shallow and often small alluvial aquifers around the world, on the other hand, receive together the bulk of the world's groundwater recharge, but their share in the global groundwater reserves is only small.

Aquifers and groundwater have been studied and mapped in varying degrees in most countries

Groundwater systems in virtually all countries have been studied and mapped in various degrees of detail. A simplified version of a global-scale compilation of these maps, produced by the WHYMAP project, is shown in Figure 2.3. The blue zones on this map represent areas characterized by main groundwater basins, green zones indicate the areas of complex hydrogeology and brown zones show areas with only local and/or shallow aquifers. The color intensity varies in accordance with the intensity of the mean groundwater recharge in the corresponding zone.

Figure 2.3

Simplified version of WHYMAP's Hydrogeological World Map



extracted from: World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP); www.whymap.org

(UNESCO et al., 2008)

2.3 Socio-economic and political setting for groundwater management

Several factors explain why private exploitation of groundwater is common — it is close to the user and needs scant treatment, it is relatively cheap to develop, and it can be turned on and off like a tap

Water used by people is either supplied by an agency, company, co-operative or other specialised entity, or it is withdrawn privately by the user. The latter — privately supplied water (self-supply) — is much more common for groundwater than surface water. The spatially more general presence of groundwater (close to the user), the relatively low needs for groundwater treatment compared to surface water, its flexibility in meeting water demands when needed and the relative easiness of private groundwater withdrawal may largely explain this.

Groundwater abstraction for irrigation — globally 70% of the total — is predominantly private, with highly decentralized decision taking, whereas domestic water supply is largely in public hands

Irrigation forms by far the largest groundwater using sector (globally 70% of all abstracted groundwater). Unlike in surface water irrigation, where public or co-operative irrigation water supply networks serve most farmers, farmers relying on groundwater for their irrigation are predominantly self-supplying. On a global basis, most of the groundwater used in the domestic water sector is supplied from public or other collective networks, although self-supply remains important in rural zones of developing countries. The situation in the industrial sector is probably in between, but it is hard to find more than only scattered information on it. Altogether it may be concluded that groundwater belongs more to the private than to the public segment of the water economy. This implies that decision-making on groundwater withdrawal is highly decentralised: numerous individuals take decisions, often without any form of co-ordination.

The profitability of groundwater use and the common pool nature of groundwater have led to competitive over-pumping and depletion, alerting governments and other stakeholders to the need for management intervention

Farmers using groundwater for irrigation do so to earn a living. Trends towards increasing groundwater withdrawal are resulting from the ambition of individual farmers to improve their income and from increasing numbers of farmers getting access to groundwater. Similar economic motivations in the industrial sector and the increasing water requirements of a steadily growing population result in additional growth of the demand for groundwater.

Given the 'common pool' nature of groundwater, under an unregulated regime there is little or no incentive for the numerous groundwater pumpers to refrain from increased pumping and to conserve groundwater. The most common scenario, in particular in water-scarce areas, is that groundwater levels will fall continuously, with negative impacts on water security, ecosystems, the environment and the groundwater resources themselves. Governments of many countries have recognized — some of them already long ago, others only recently — that effective self-correcting mechanism are unlikely to develop in such a setting. Hence, they conclude that groundwater resources management interventions are necessary to control abstraction and resource conservation.

Many governments have reacted by declaring groundwater public property — although this can raise problems of existing rights — or they have sought to regulate private rights

One of the complicating factors is the perception of many self-supplying groundwater users that they are the owner of the groundwater below their land, or at least that they would have unlimited user rights. In response, there is a tendency among countries to declare the ownership of groundwater resources legally to be vested in the state. This marks a fundamental step forward in the attempts to get a grip on uncontrolled situations with a vast number of players. It legitimizes government control measures that — among others — incorporate externalities properly. Nevertheless, political preferences elsewhere may opt for private ownership or user rights (such as in Texas (USA), India and the Canadian provinces Ontario and Prince Edward Island) or the complication may arise that legal rights acquired in the past cannot be overruled immediately by new legislation (e.g. in Spain).

Pollution is also a problem, with the complication that, unlike users, polluters have no incentive to change

Groundwater management deals not only with groundwater quantity but also with groundwater quality. Pollution by human activities is one of the major concerns. Groundwater polluters (or potential polluters) and groundwater pumpers are in principle different groups (although there may be overlap), thus self-interest cannot be expected to motivate polluters to change their behavior to the better. In many cases it may be unattractive for them to change because of the cost involved. Awareness raising on groundwater pollution and regulations to curb it are essential.

Strong, centralized states can impose regulation, while other states may seek indirect management approaches such as adjusting the incentive structure

The political system, power and culture have a major influence on what groundwater management policies and approaches are chosen. In countries where the state's political power is centralised and strong (like China, Oman) it is relatively simple and attractive to enforce direct restrictive measures. In other countries (like India) more indirect management approaches are preferred, e.g. by regulating energy supply and energy prices. Under powerless or errant political regimes there may be little or no political commitment to water resources management.

Other policy goals like food security or poverty reduction may conflict with goals for groundwater management

Political goals and priorities for other sectors may interfere with the objectives of groundwater resources management. E.g., several countries maintain very low energy prices and provide other subsidies to the irrigation sector in order to promote food security and alleviate poverty in rural areas. However, these subsidies may form additional obstacles in the pursuit of controlling groundwater resources.

Management may also be guided by international agreements, either on transboundary aquifers or best practice codes such as the EU Water Directive

Finally, the political setting may include international components, in the first place in the case of transboundary aquifers. Using and managing groundwater of the national segments of such aquifers is primarily according to national policies and customs. Efforts towards a coordinated or shared management of transboundary aquifers adds an international dimension, that may include endorsement of the Draft Articles of the International Law of Transboundary Aquifers, agreements between neighboring countries in the form of treaties, and development of coherence between management measures across the international boundaries. A second example is the Groundwater Daughter Directive of the European Water Framework Directive. EU member states are politically committed to this directive that pursues a good state of the groundwater resources by a number of concrete actions.

2.4 Roles and functions of groundwater and the subsurface

Groundwater use for domestic water supply

Only 8% of groundwater recharge is abstracted each year — but this may reach 50% in some countries

The total global withdrawal of groundwater, as estimated for the year 2010, is 982 km^3/year (equivalent to 8% of the mean global groundwater renewal). India, the USA and China, abstract about half of this annual volume, while the top-10 groundwater abstracting countries withdraw two-thirds of the global total. Groundwater abstraction thus is irregularly distributed across the globe.

Globally, just over one fifth of abstractions are for domestic supply…

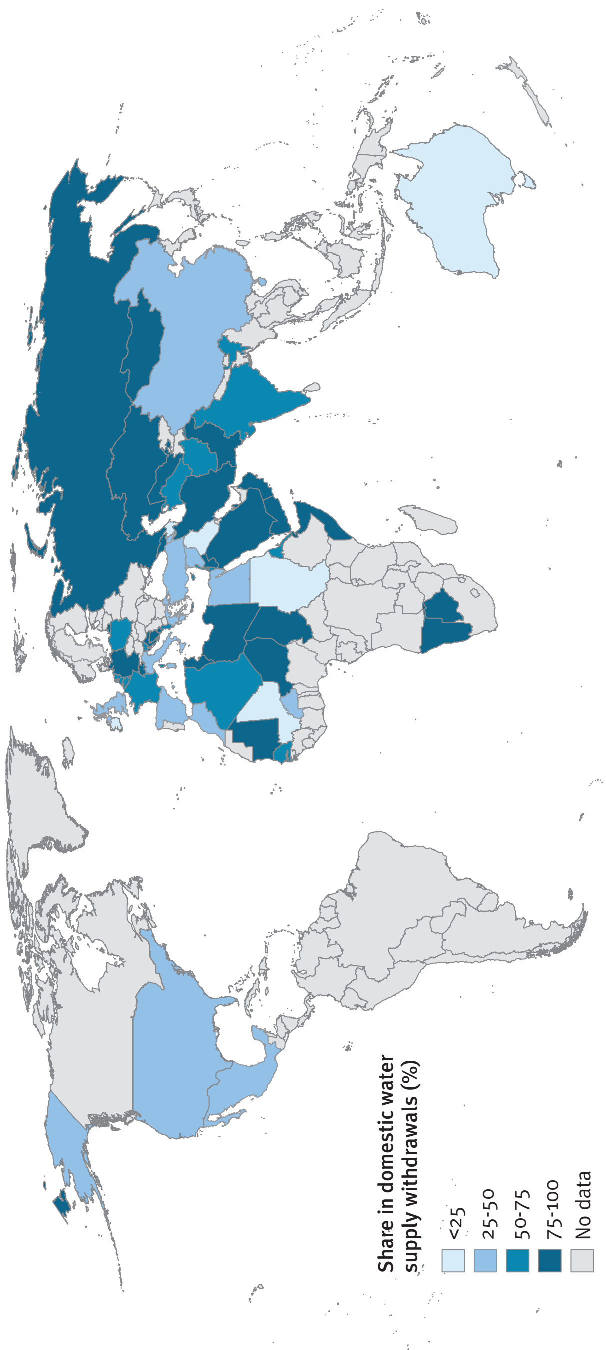
Approximately 21% of the total groundwater abstraction is aimed for domestic water supply, which includes drinking water, water for washing/cleaning and cooking, as well as water for public services, offices, shops and small industries connected to a public water supply network.

…and in most countries, groundwater accounts for the bulk of domestic supply and probably half of the world's population get their drinking water from groundwater

The share of groundwater in the total volume of domestic water supply varies considerably from country to country, as is illustrated in Figures 2.4 and 2.5. Averaged over regions or large countries, this share varies from around 71% in South Asia, 70% in Europe (including Russia), 66% in Australia, 55% in the Middle East, 33% in the USA, 32% in North Africa to 29% in China. Up-to-date and reliable national data are missing for South America, most of Sub-Saharan Africa and South-East Asia. Nevertheless, it may be concluded that groundwater plays a key role in the domestic water sector, being the source of drinking water for probably half the world's population. It should be noted that the volumetric share is an imperfect indicator of the relative importance. It does not take into account the fact that groundwater may be the only source of water available (dry regions) or much better affordable than surface water (sparsely populated rural areas).

Figure 2.4

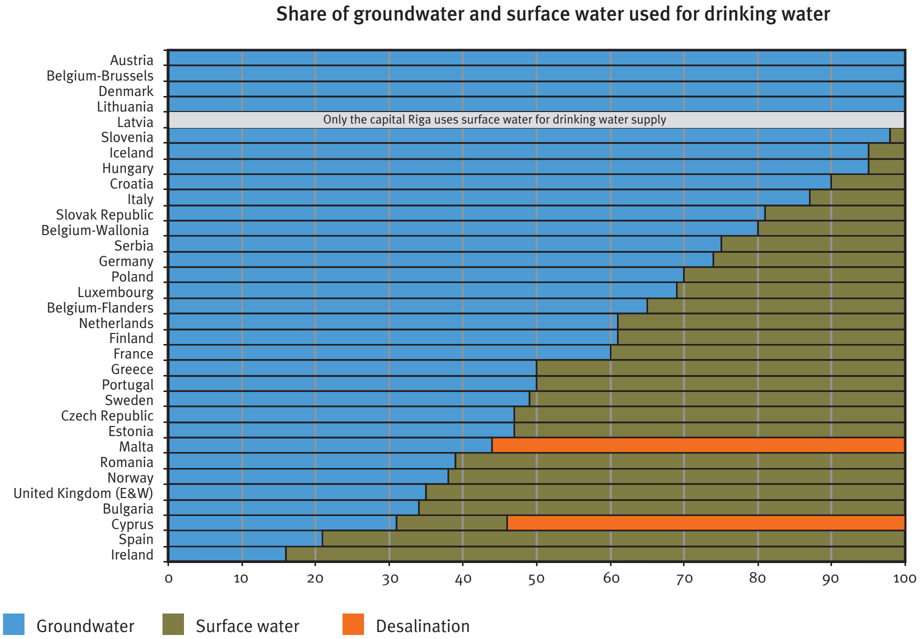
Share of groundwater in freshwater withdrawals for domestic water supply



(Margat & Van der Gun, 2013)

Figure 2.5

Groundwater dependence in drinking water supply in Europe



(Chilton and Smidt, 2013; modified from EC, 2012)

Domestic groundwater schemes range from single family wells to large wellfields supplying cities

Schemes for the withdrawal of groundwater for domestic purposes are extremely variable in size and degree of sophistication: they range from a single well used by one family or a village community to multiple well fields as a component of complex metropolitan public water supply systems.

Use of groundwater for domestic purposes is likely to increase, particularly in poor, dry rural areas where it is often the most accessible resource

The relative importance of groundwater in the domestic water sector is likely to increase in the future, as it often turns out to be the preferential source to be tapped in the endeavour to achieve the MDG-7 and the newly proposed SDGs on Water. In Africa, for instance, approximately 80% of the 300 million people who have no access to safe water supplies live in rural areas, and it is the rural areas where the comparative advantage of groundwater tends to be most outspoken.

Groundwater use for agricultural water supply

About 70% of groundwater abstractions worldwide are for agriculture

Groundwater abstracted for agricultural water supply is estimated to correspond to 70% of the total global withdrawal of groundwater (FAO, 2013). In principle this includes not only water for irrigation, but also water for livestock. The volumes corresponding to livestock water use are difficult to estimate, because a significant part of the water used in this category may be included in the statistics on domestic water use (shared water supply system). Anyhow, the global quantity of groundwater used by livestock is modest compared to that used for irrigation.

...which irrigates about two fifths of the world's irrigated area

In terms of volume, the estimated 688 km3 of groundwater withdrawn annually for irrigation is probably close to one quarter of the annual volume of freshwater withdrawn for irrigation, but groundwater supplies to an estimated 39% of the world's total irrigated area (Siebert *et al.*, 2010). The discrepancy between these two fractions can be explained by on average substantially less conveyance losses in groundwater irrigation, compared to surface water irrigation. Figure 2.6 gives an impression of the spatial variation of the share of groundwater in irrigation consumptive use.

...and accounts for an even higher share of value added from irrigated agriculture

In terms of value added by the irrigation sector, the share of groundwater irrigation may even be considerably higher than 39% (share in consumptive use), because the predictability of groundwater availability eliminates the risk of cash crop harvest failures due to water shortage.

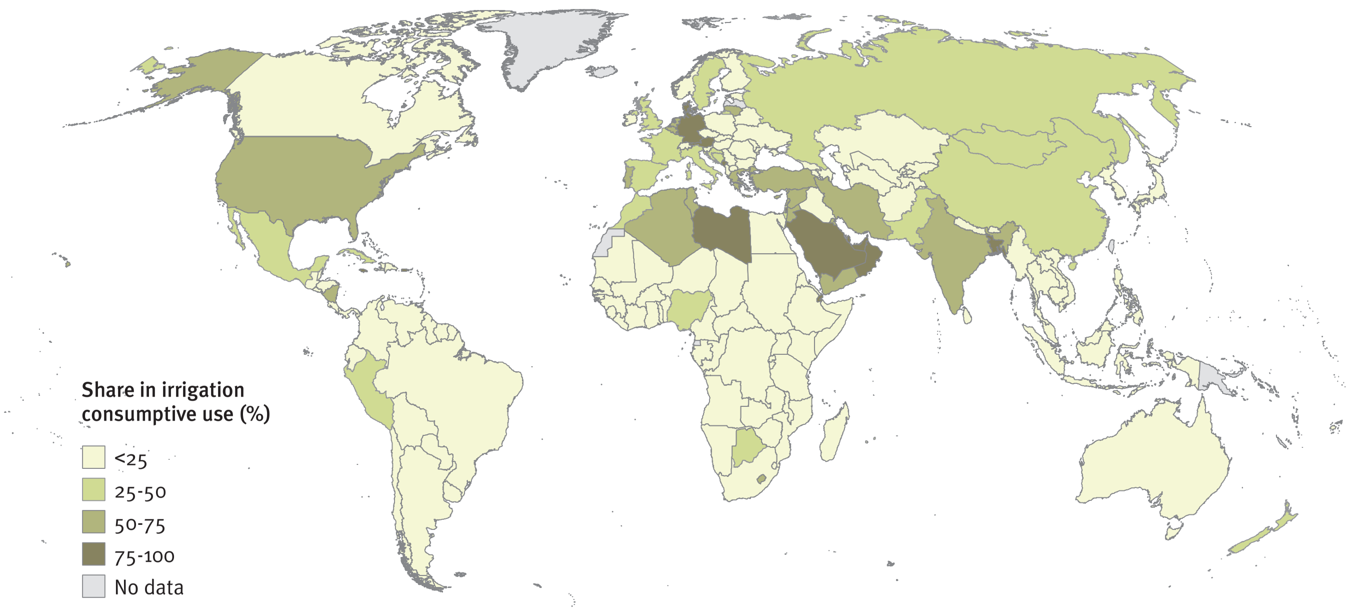
Groundwater use by industry and mines

Water has multiple uses in industry and mining

Water use in the industrial sector is extremely heterogeneous, in terms of the quantities used, the water quality required and the role of water in the industrial process. Water may be the

Figure 2.6

Share of groundwater in irrigation consumptive use



(Margat & Van der Gun, 2013)

main component of the product to be sold (e.g. mineral water, beer and soft drinks industries), or it may play an important role during processing (e.g. food processing industries), but in other industrial branches it may be used predominantly for washing, cleaning or cooling. A considerable part of groundwater withdrawn by the mining industry may even have no envisaged use at all, but is simply pumped to remove water from the subsurface zone where mining operations take place. These quantities of mine drainage water, like other drainage water, are usually not included in the statistics on groundwater withdrawal.

Although highly variable by country, groundwater used in industry accounts for about 9% of global abstractions…

Only around 9% of the global groundwater abstraction is pumped by the industrial sector, but the percentage varies considerably between countries. In a number of industrialized countries (Estonia, Norway, Hungary, Japan, The Netherlands and Ireland), the industrial sector is even the largest groundwater-using sector. The variation between countries in the share of groundwater in the total industrial water withdrawals is shown in Figure 2.7. As can be noted and expected, this share is very high in arid countries such as Burkina Faso, Libya, Mongolia, Namibia, Oman, Saudi Arabia and Yemen.

…with typically much higher value added per unit of groundwater withdrawn than in agriculture

The added value per unit of water used in industry is usually high, compared to water use in irrigation. Therefore, the volumes of groundwater used in industry are a poor indicator of their economic impact.

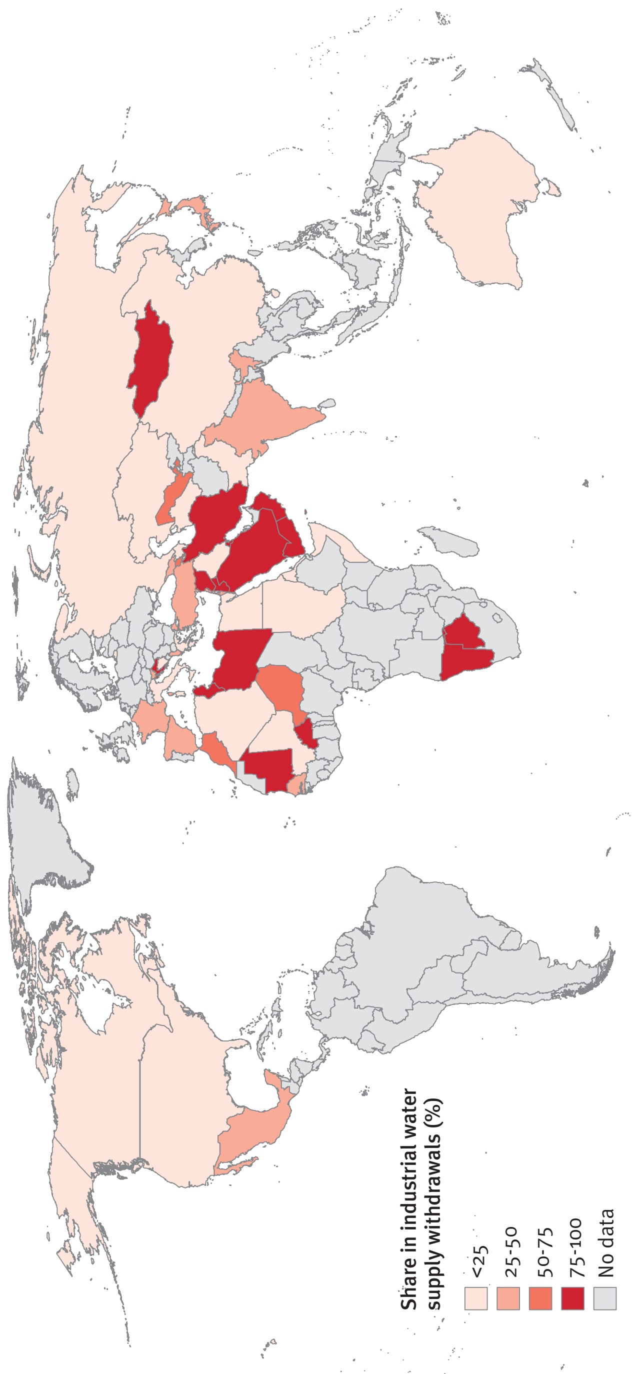
Groundwater use in energy generation and development

Groundwater plays an important role in the development of natural energy resources

The provision of cooling water for thermal power plants is one direct use of groundwater that can be overlooked. Emergency cooling water supplies may come from groundwater where surface supplies are absent or can be compromised — even in coastal estuarine plants such as those in the Thames estuary.

Figure 2.7

Share of groundwater in industrial water withdrawals



(Margat & Van der Gun, 2013)

Groundwater may be used in all phases of oil and gas production, with risks to both quantity and quality of groundwater reserves

In the oil and gas sector, drilling exploration and production wells requires water, which is by volume the main component of drilling mud and often abstracted from local groundwater reservoirs. During the production phase, secondary recovery techniques are applied after the natural reservoir drive has faded. Injecting water — often groundwater — is one of the techniques applied to force the oil to the surface. In general, groundwater abstracted for oil and gas operations is re-injected, consequently it does not put much pressure on groundwater quantity. Nevertheless, the injected water may have significant consequences for the local groundwater quality.[3]

Shale gas recovery injects water with chemical additives, bringing risks for groundwater quality

Shale gas is a natural energy resource gaining interest rapidly. Countries with estimated large volumes of recoverable shale gas are (in order of decreasing reserves): China, Argentina, Algeria, USA, Canada, Mexico, South Africa, Australia, Russia and Brazil (US Energy Information Administration, 2013). Hydraulic fracturing or hydro-fracturing ('fracking') is applied to enhance the permeability of the reservoir rock, which injects large quantities of water with acids or other chemicals added. This is why in several countries there is a ban on shale gas exploitation.

Geothermal energy production uses groundwater as an energy carrier but does not threaten groundwater quantity or quality

Geothermal energy is even more closely linked to groundwater than the above mentioned fossil energy sources, because in this case groundwater itself is the energy carrier.
The temperature of groundwater, like that of the rocks of the Earth's crust, increases with depth; the thermal gradient is on average 30° C per km, but where thermal anomalies are present it may be considerably higher and temperatures up to 400°C and more can be reached at economical depths. The heat energy of groundwater can be used either directly (e.g. for heating purposes) or indirectly, after conversion into electricity. Geothermal energy remains today an underdeveloped energy resource, compared to the huge quantities of thermal

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[3] Petroleum occurs in deep sedimentary basins and is produced in many countries around the world: top oil-producing countries are Saudi Arabia, Russia, USA, Iran, China, Canada, Mexico, UAE, Kuwait and Venezuela.

energy stored and moving within the Earth's crust. After extracting the geothermal energy, the groundwater is usually returned to the subsurface, thus the impact on groundwater quantity is minimal. Geothermal energy development in the low-temperature range (30° to 90°) is significant in countries like Iceland, Hungary, Japan, New Zealand, Germany and China. Development of geothermal resources in the high-temperature range can be found in Italy, Russia, Mexico, USA, Indonesia, The Philippines, Japan, Australia, Papua New Guinea, New Zealand, the Azores and Guadeloupe.

Sub-surface heat storage also uses groundwater but is a low risk, non-consumptive use

Subsurface heat storage is a related technique, but applied in the very low energy domain. Shallow groundwater is used for temporary storage of surplus heat, with the purpose of recovering it later when it is needed, using heat pumps designed for individual or collective heating systems. The application of this technique is rapidly expanding in many European countries, the USA, Canada and Japan. Again, this is non-consumptive use of groundwater, because the pumped groundwater is usually re-injected.

Groundwater and the environment

Groundwater plays a key role as an agent of environmental stability but is vulnerable to changes in flows in the hydrological cycle and to pollution, the consequences of which are often slow to become apparent

Groundwater is looked at by most people predominantly as an extractable natural resource, but it is at the same time also an agent of environmental stability underpinning many local and transboundary flow processes. These environmental aspects have been recognized in comprehensive reviews of the agency of both groundwater and the aquifers through which it is transmitted (Morris et al. 2003). It plays a role in many geological processes, hidden from public view and taking place at an extremely slow pace but with profound implications for groundwater quality either in attenuating surface pollutants or acquiring geochemical imprints. For these reasons the environmental values associated with groundwater flow and aquifer state (hydraulic and geochemical) may only be realized after irreversible damage to natural flow systems has occurred. Anticipating the impacts of flow modification and pollution practice is one of the key groundwater management challenges.

Waterlogging and salinization are particular challenges

Karst regions, with disappearing and reappearing streams, large springs, caves, dolines and other irregularities of the land surface, are a clear, immediate example. But the extent of shallow groundwater circulation in productive alluvial and coastal plains requires drainage to avoid waterlogging and accumulation of saline and sodic soils. Under irrigated conditions this may form such a restriction to land use that artificial drainage is needed, with the result that nowadays more than 160 million hectares around the world are artificially drained: in the USA, China, Pakistan, India, Mexico, The Netherlands, Lithuania, Denmark, Serbia, Hungary and elsewhere. In many other zones, shallow groundwater levels play a positive environmental role, by sustaining springs, base-flows of streams and valuable wetland ecosystems in all parts of the world. Groundwater plays also an important role in the stability of the land surface in soft geological formations: changes in groundwater pressure conditions may contribute to occurrence of land subsidence or landslides.

Groundwater and climate variability/climate change

Groundwater is an invaluable buffer against rainfall variability and drought conditions

Climate variability — in the sense of both predictable and unpredictable fluctuations of weather conditions on the short and medium term (less than, say, 10 to 15 years) — is a complicating factor in the water sector. This is particularly obvious in semi-arid regions, where the rainfall regime may produce predictable water scarcity during the annual dry seasons, but also produce unpredictable periods of droughts. Lack of drinking water or irrigation water, failing harvests and other severe repercussions can be prevented if significant buffers are available. Groundwater is usually the most important buffer under such conditions. It enables life to continue even during very long periods without any rain.

Longer term, climate change may reduce groundwater availability in shallow aquifer systems, whereas larger systems with extensive storage can make a huge contribution to water security

Climate change is perceived on a human time scale as trends rather than as fluctuations in weather conditions. It is a long-term phenomenon, but this does not mean that preparations for anticipating climate change can wait. On the contrary, predicted changes — in spite of significant uncertainties — suggest that many areas in the world will face increasing water security problems, caused by less concentrated or more concentrated rainfall, higher evapotranspiration rates and increased water demands. It will require much time to adapt to such less favorable conditions. The fate and role of groundwater in this context is twofold. On the one hand, the freshwater resources of many shallow and vulnerable groundwater systems (e.g. shallow and narrow alluvial aquifers, coastal aquifers and thin aquifers of very flat islands) will be reduced. At the other hand, groundwater systems with large volumes of freshwater in storage are likely to play an important role in adapting to climate change in areas where surface water and green water resources are bound to degrade considerably. The groundwater buffers then will maintain water security in such areas, like they do in areas where significant rainfall and stream flow are missing (such as in large parts of Northern Africa).

Interactions between land and water

Availability of groundwater often drives decisions on land use — but it is vulnerable to any resulting pollution risk

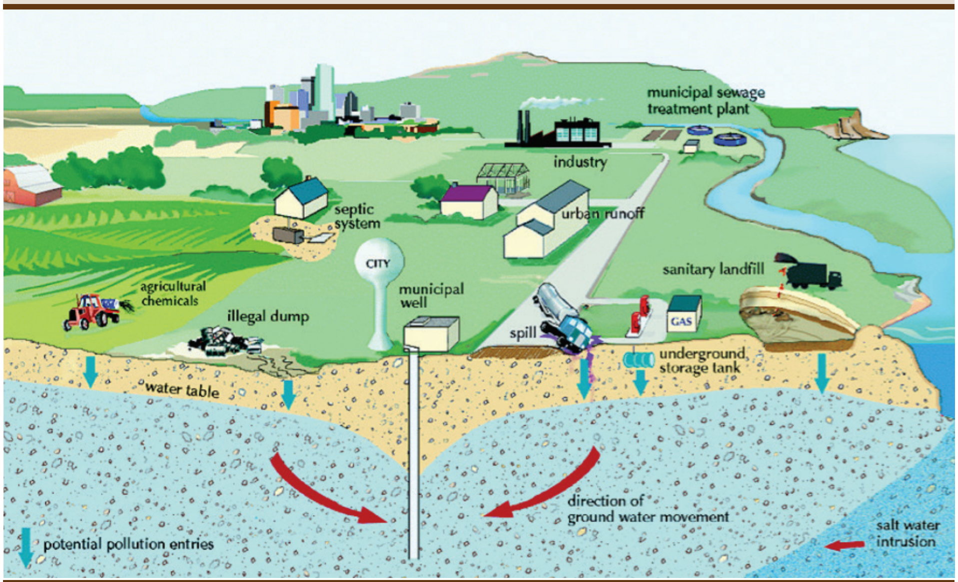
Groundwater recharge and groundwater quality are conditioned by land use. The presence and local characteristics of groundwater defines often for which types of use a certain piece of land is suitable, while groundwater pollution risks are highly dependent on the adopted type of land use and land use practices. Figure 2.8 gives an impression of the different categories of pollution sources related to different types of land use. Interactions at some depth below the surface are commented upon in section 2.4.8.

Integrated approaches to water resources management (IWRM) are becoming more common but land use planning and management are usually quite separate — with consequent risks to groundwater

The described interactions are generally occurring in all parts of the world. It would be beneficial to tune policies and management in the different interrelated domains to each other, in order to promote coherency and synergy. On a global scale, only significant progress in this sense can be observed between groundwater and surface water management policies; these are to a gradually increasing degree addressed jointly in an integrated water resources management approach (IWRM). Land use planning (if practiced at all) still remains in most countries a separate policy field, not linked to groundwater resources management and operating in a legal and institutional setting that is completely unrelated to groundwater management.

Figure 2.8

Schematic picture of common sources of groundwater pollution



2.4.1 Use of the subsurface space and its resources other than groundwater

In addition to groundwater, there are many other resources and possible activities in the sub-surface domain

Apart from the withdrawal of groundwater, the shallow and deep subsurface domains offer many more opportunities, functions and challenges to humankind. Table 2.1 shows the main categories of the use of subsurface space and subsurface resources other than groundwater.

Many sub-surface exploitation activities use groundwater, and they also bring risks of damage to the aquifer structure and of pollution of groundwater

Several of the activities listed in Table 2.1 have special and often significant requirements related to groundwater. For instance, mining activities usually require subsurface zones to be drained and the same is true at shallower depths for underground railways, tunnels, car parks and several other uses of the underground space.

Table 2.1

Principal human uses of subsurface space and subsurface resources other than groundwater

Category	Type of activity	Geographic distribution
1. Mining	Extraction of minerals	In zones where profitable mineral resources have been identified (scattered over the globe).
2. Subsurface energy development	Oil and gas development	In zones where profitable hydrocarbon resources have been identified (in major geological basins on- and off-shore).
	High-enthalpy geothermal energy development	Areas of favorable temperature anomalies (e.g. in USA, Japan, Iceland, Italy, Central America, Indonesia, Philippines, Kenya, China (Tibet), etc.)
	Low-enthalpy geothermal resources development	Major sedimentary basins (e.g.: France, Germany, Brazil, etc.)
3. Disposal and storage of hazardous wastes	Disposal by deep well injection	Often associated with mining, or with oil and gas industry
	Subsurface storage of radioactive waste	Most of it in selected countries, e.g. USA, France, Russia, Japan and India
	Nuclear weapons testing and nuclear power accidents	E.g., Western USA and French Polynesia (tests); Russia and Japan (accidents)
4. Injection and recovery	Solution mining (e.g. using acids and other lixiviates)	In selected mining areas
	Reservoir management by injecting residual geothermal fluids	In geothermal energy development areas
	Storage of hydrocarbons and fluids associated with oil and natural gas production	In or near oil and gas production areas
	Hydraulic fracturing or 'fracking'	In zones where shale gas is exploited
	Carbon capture and sequestration	Major projects in North Sea, in Canada and in Algeria.

Table 2.1

(Continued)

Category	Type of activity	Geographic distribution
5. Construction into the underground space	Pipelines, sewerage systems and cables	Very general around the world, in particular in developed countries
	Tunnels and underground railways	In particular in many urban centres around the world.
	Underground car parks and other underground constructions	In particular in urban areas in industrialized countries where space is scarce.

(based on Van der Gun et al., 2012)

Geothermal energy development uses groundwater as a carrier of energy, while the injection of water into deep subsurface reservoirs is practiced in the oil and gas industry. Beyond their requirements related to groundwater, all mentioned subsurface activities modify the subsurface environment also in other ways, either by removing substances from the subsurface, or by introducing new substances into it, or otherwise. Typical impacts are land subsidence or other terrain instabilities, but in particular also pollution risks. The latter are inherent to all subsurface activities, but are most significant in cases of injection into the subsurface of waste (solids and fluids) and other forms of underground waste disposal or temporal storage.

There is little or no coordination of these activities, so there is no coherent mitigation of risks

The different uses of the subsurface tend to be planned and implemented independently from each other and from groundwater development and management. Coordination between their governance and that of groundwater (laws, mandated institutions, policies) is still rarely observed.

2.5 Rationale for managing and governing groundwater

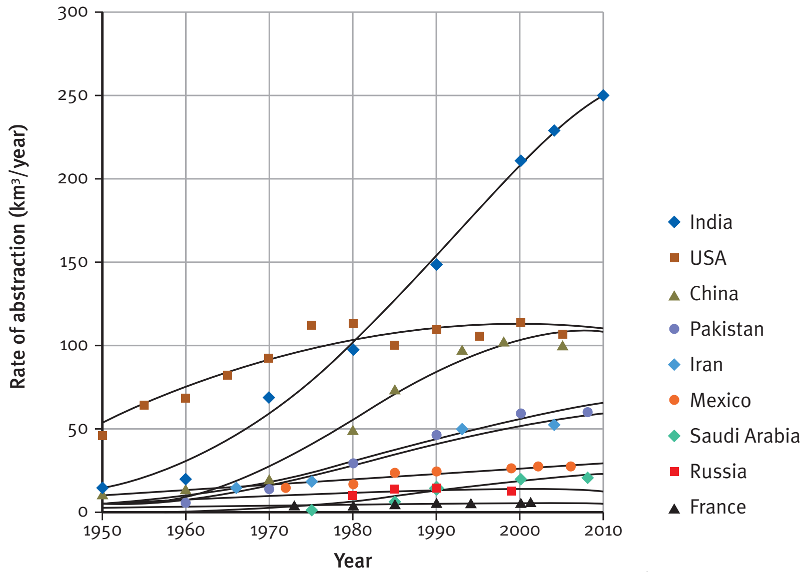
The accelerating rate of socio-economic change

Since the 1950s, the rate of abstraction of groundwater has increased very rapidly

In modern times, especially since the middle of the 20th century, the role of groundwater and the state of the groundwater resources have changed in an unprecedented way. Groundwater abstraction and use have in most countries increased very fast, driven by demography, scientific and technological innovation and socio-economic development. Figure 2.9 shows the trends in groundwater abstraction in a number of countries that withdraw large quantities of groundwater.

Figure 2.9

Evolution of groundwater abstraction in selected countries



(Margat & Van der Gun, 2013)

This increased groundwater use has brought enormous benefits – but also resulted in depletion, with consequent high costs

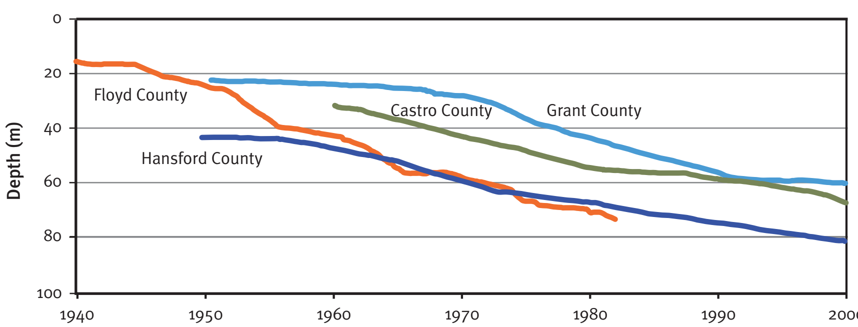
The enormous social and economic benefits of the enhanced role of groundwater are beyond any doubt, but the pressure of more intensive groundwater abstraction have at same time caused a range of problems in several areas and is producing threats elsewhere. These problems range from the exploitation of groundwater becoming more difficult or expensive to significant degradation of the groundwater resources or negative impacts on the groundwater-related environment. They have in common that they all result from declines of the groundwater levels, often even very significant declines (see Figure 2.10).

Depletion and pollution are also seriously affecting quality, particularly at shallow depths

Furthermore, groundwater quality is significantly degrading in many aquifers, not only as a result of more intensive groundwater abstraction (e.g. causing sea water intrusion), but also due to polluting activities that are mostly driven by demographic development and changing lifestyles. In large parts of the world, pollution of groundwater has become an even more prominent problem than groundwater depletion due to intensive exploitation.

Figure 2.10

Example of long-term declines of groundwater levels: unprecedented change in groundwater state on the High Plains, USA

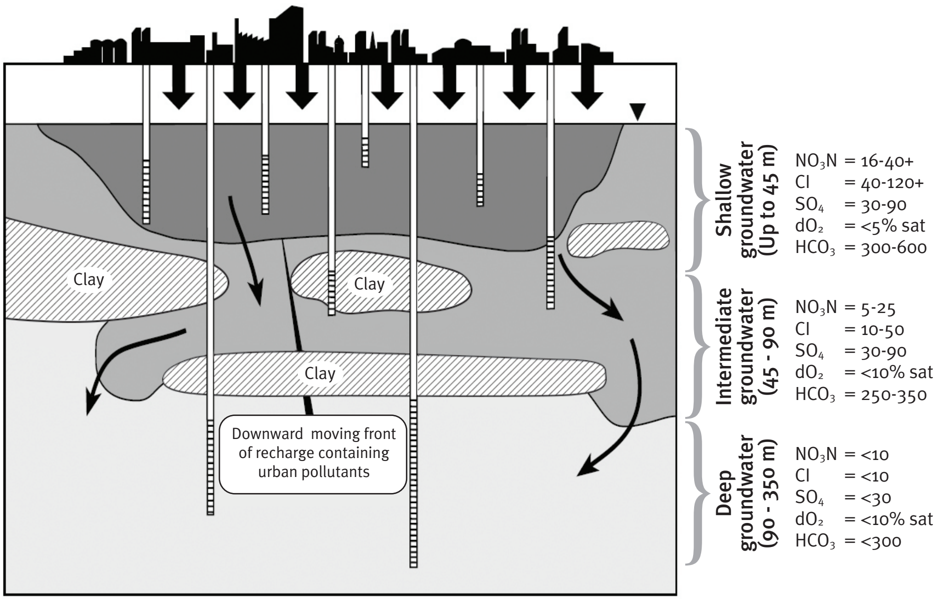


(Margat & Van der Gun, 2013)

As a consequence, a very significant share of recent groundwater recharge has been polluted already, which has degraded groundwater quality in particular at relatively shallow depths (see e.g. Figure 2.11).

Figure 2.11

Stratification of diffuse urban pollution below the Bolivian city of Santa Cruz



(Chilton, 2006)

Only collective action can balance stakeholder interests, safeguard the resource and protect the environment

Planning optimal aquifer-wide use of the opportunities offered by the groundwater resources and preventing or controlling problems that result from the changing state of groundwater resources are beyond the power of individuals. There is ample evidence that the sum of individual actions related to groundwater, driven by private interest, usually does not result in a socially most desirable overall situation. This calls for managing and governing groundwater in a way that respects and balances the interests of all stakeholders, while safeguarding the resource base and protecting the interconnected environment.

Groundwater/surface water interactions and other linkages

> *Groundwater is linked to — and ideally should be managed in cooperation with — other activities, including: overall water resources management; land use; other sub-surface activities; ecosystems and the broader environment; and energy*

Groundwater and **surface water** are closely interlinked in almost any area on Earth. This is already so under natural conditions, but is intensified by human action, such as water withdrawal, artificial drainage, irrigation, etc. Likewise, there are considerable interactions between groundwater and **land use**: groundwater conditions affect land use, and land use — in turn — affects groundwater quantity and quality. At various depths below the ground surface, shallow and deep, there is an increasing number of **human activities that may change subsurface conditions** and thus have the potential to affect groundwater: mining activities, development of oil and gas, subsurface storage, hazardous waste disposal, and the use of subsurface space. Furthermore, changes in groundwater state may have repercussions for **ecosystems and other aspects of the environment**. The link between groundwater and energy is also evident, not only because of groundwater's role in energy development (geothermal energy, oil and gas), but also because groundwater withdrawal requires very significant inputs of energy in various countries. Linking these and other inter-related sectors to one another requires governance and management approaches.

Impact of groundwater use on high-level societal goals

> *Groundwater is making a major contribution to socio-economic development — and more could be done*

All the regional diagnostics point to the significant and continuing contribution that groundwater makes to public well-being and health (by improved domestic water supply), poverty reduction (through open access) and economic stimulus (e.g. by enabling more or more profitable irrigation). The characteristics of groundwater allow the benefits of this resource to be spread among the entire population, thus contributing to social equity goals. In certain areas there are still opportunities to expand this beneficial use of groundwater. Utilizing non-consumptive services of groundwater (outlined in section 2.4) have resulted in additional contributions to local economic development.

However, human activity is threatening these gains, affecting both the quantity and quality of the resource and the economic activity that depends on it

Human interactions with groundwater produce changes in the state of groundwater, in terms of quantity and quality. The observed changes in groundwater state — irrespective of whether they are associated with groundwater withdrawal, polluting activities or other causes — have predominantly negative impacts. These changes include steadily declining groundwater levels (equivalent to a loss of groundwater reserves) and groundwater quality degradation. The multiple impacts counteract economic development and may form a threat to the sustainability of the groundwater resources and their services, and of groundwater-related ecosystems and other components of the environment.

Why 'good' groundwater governance and management make sense

Improving governance and management is thus essential to protecting and increasing the benefits to be gained from groundwater

This chapter has highlighted the huge value of groundwater, the large dependency of humans and ecosystems on it, and the variety of problems that threaten groundwater or its functions. Setting a frame for groundwater governance and undertaking management initiatives can prevent or at least slow down and reduce degradation of the groundwater resources and contribute to its sustainability, as well as to its optimal allocation, use and protection. The range of benefits that can be produced by adopting a groundwater governance frame in which to apply progressive management will often more than justify the means.

3. The global state of groundwater governance

"The effective governance of groundwater requires proactive measures by the State and a cultural change among users".

(Contribution of Chile in: Tujchneider, 2013)

3.1 Reference framework

Organization of this chapter

This chapter summarizes the status of groundwater governance around the world. The chapter begins with a statement of the framework used in the analysis (Section 3.1). The chapter then discusses the importance of taking into account the area-specific setting for groundwater governance, which has to reflect the issues and challenges locally present in relation to groundwater (Section 3.2). This is followed by a discussion of general policy responses (Section 3.3). Subsequent sections then discuss in detail the four components of governance: **actors**, their roles and modes of interaction (Section 3.4); **legal and institutional frameworks** (Section 3.5); **policies and plans** and their development and implementation (Section 3.6); and **information, knowledge and science** (Section 3.7). Section 3.8 then discusses special cases of groundwater governance, particularly the challenge of transboundary groundwater.

Conclusions from the discussion in the chapter are then summarized in a final section (Section 3.9).[4]

Current status of groundwater governance around the world

> *Although the findings of the Project show that groundwater governance is highly diverse around the world, two common lessons have nonetheless emerged*

The current status of groundwater governance around the world cannot be easily summarized. The chapter presents a kaleidoscopic picture, but nevertheless incomplete and to some extent subjective. Although an unprecedented wealth of information on groundwater governance has been collected by the Groundwater Governance Programme, this does not yet provide a systematic and reliable description of groundwater governance variation between regions and countries. Primarily this is because of the enormous diversity of conditions around the world. Further, the information was often linked to a small area or to a special case, and sometimes open to interpretation. Likewise, although there are differences between the findings reported at each of the project's five regional consultations, these are not necessarily representative or balanced. Nevertheless, two common lessons have emerged:

- **The state of groundwater governance depends very much on the groundwater management stage and on the economic conditions in the country concerned.** For this reason, groundwater governance principles are generally more embedded in relatively wealthy industrialised countries than, for example, in most Sub-Saharan African countries. Some of the greatest governance challenges are likely to be felt in rapidly developing countries in which governments can struggle to keep up with the rapid pace of change.

- **The focus of groundwater governance varies with the local needs and conditions.** Hence the focus on groundwater resource allocation in arid and semi-arid countries, on groundwater development for domestic water-supply in Sub-Saharan Africa, and on safeguarding groundwater irrigation for many millions of small farmers in South Asia. In Europe and North America increasing priority is being given to groundwater pollution control and aquifer and ecosystem protection, and paying some attention to the interaction with land-use and energy policies.

[4] The description of the current status of groundwater governance is largely based on the five regional diagnostic reports of the Groundwater Governance Project (Tujchneider, 2013; Zubari, 2013; Kataoka & Shivakoti, 2013; Braune & Adams, 2013; Chilton and Smidt, 2014). For practical reasons, reference to these sources has been made only sparsely in the text.

There are large governance gaps almost everywhere but the focus for future strengthening of governance varies according to development priorities and current risks

There is often a large gap between the present state and focus of groundwater governance and that which is actually needed and this is seen between and within the regions. Where development to meet basic water supply and sanitation requirements remains a major priority, much of the shorter to medium term governance focus needs to be on issues like financing, contracting and supervising such activities to ensure value for money, sustainability of supply sources and equity of service provision. There are also important governance requirements related to transparency and accountability, and the avoidance of corruption in the provision of contracted services. Many governments struggle to provide the institutional and technical capacity to meet these needs.

Overall, strengthening groundwater governance is a "work-in-progress throughout the world"[5]

Given the limited awareness related to groundwater and the complexity of the challenges to be addressed, it is not surprising that the diagnostic reports of the five regional consultations indicate that the **state of groundwater governance is still rather poor in many countries**. Some of the major issues and changes are discussed below.

Groundwater governance issues and challenges

The range of issues to which governance will have to be responsive is broad — over-abstraction and pollution are problems to be addressed almost everywhere but other issues arising locally will also need to be tackled

Governance over basic permissions to access and withdraw groundwater has been vague. Arguably the scale and intensity of human demand upon groundwater has outstripped general 'de minimus' provisions in water law and the pollution of aquifers continues unabated. Technology has favoured access to the rich at the expense of access for those most in need, the vulnerable poor in rural and urban settings. At the same time the expansion of urban areas has expanded the groundwater footprint involving competition between low value agricultural

[5] Shah, 2009

production and high value urban/industrial uses. These trade-offs are rarely negotiated in structured governance frame.

There is no blue-print for good governance that would suit all countries of the world perfectly. Ideally, governance should be evolving in each location to respond to such objectives, issues and challenges. In the description of the current status of groundwater it is therefore important to relate governance to the local realities and to observe to which extent the given local governance set-up is capable of addressing the local issues and challenges. **Intensive groundwater abstraction** and **groundwater pollution** are issues or potential issues in virtually all countries of the world, thus governance will almost always have to be developed to address these issues. The geographic spread of some other issues may be less universal, e.g. **groundwater-induced land subsidence**, **seawater intrusion**, **water-logging** or **deficient rural water supplies**. Challenges may also vary from area to area: they could include improving rural water supply and developing sewerage systems in some areas, whereas elsewhere the priorities may focus on wetland conservation and other sustainability goals. Whenever certain issues or challenges are considered to be important, they should be reflected in the governance arrangements: in the gamut of actors involved, legislation and institutions, policy and planning, and information, knowledge and science.

Development goals for groundwater commonly found

> *International forums have set some general objectives for groundwater governance and management, notably: expanding use of groundwater for drinking, household water and sanitation; improving water productivity; ensuring protection of the ecosystem and broader environment; and cooperating on transboundary water management*

At many water related global summits, assemblies, forums and similar events, global ambitions and goals have been formulated, promoted and endorsed by national representations. Each of the promoted goals makes its own specific demands upon governance. Important international goals, priorities and recommendations in this context are the following:

(a) *Millennium Development Goal No 7* (Johannesburg Earth Summit, 2002), that calls for ensuring environmental sustainability. Relevant in relation to groundwater are in particular target 7A (“Integrate the principles of sustainable development into country policies”) and target 7C (“Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation”)

(b) *Draft Articles on the Law of Transboundary Aquifers*. These articles are meant to stimulate and facilitate joint management of transboundary aquifers by providing sound principles for co-operation that can be adopted by the neighbor countries involved.

(c) *Stockholm Water Week recommendation to the Rio+20 UNCSD in Rio de Janeiro (2012):* "Over and above achieving the Millennium Goals, we call for a universal provisioning of safe drinking water, adequate sanitation and modern energy services by the year 2030"(Stockholm World Water Week 2011)

(d) *Rio+20 United Nations Conference on Sustainable Development Statement (Rio de Janeiro, 2012)*. The outcomes include a common vision on sustainable development, which recognizes that poverty eradication, sustainable patterns of consumption and production, and managing the natural resource base of economic and social development are essential requirements. The 'water and sanitation section' of the Framework for Action reaffirms previous UNCSD commitments (like the MDGs), recognizes the key role of protecting and managing ecosystems sustainably, underlines the need for measures to address floods, droughts and water scarcity, and stresses the need for measures to reduce water pollution and to raise water efficiency.

(e) *Stockholm Statement 2013: A call for a Sustainable Development Goal on Water.* This SDG stipulates that by the year 2030, the following should have been achieved: (i) a doubling of global water productivity; (ii) a realization of the human right to safe drinking water and sanitation; (iii) increased resilience to water-related disasters.

(f) *Budapest Water Summit Statement (2013)*. Key policy recommendations formulated at this summit are:

- Creating smarter targets to ensure universal access to safe, gender-responsive and sustainable water and sanitation and hygiene
- Integrated consideration of water within its management context and in all basic services sectors
- Fostering good water governance
- Using water to create growth and 'green economies'
- Creating new micro and macro, private and public financing methods.

This is not an exhaustive list of global goals and priorities, but the subjects reflect key priorities on water as perceived by the global water community and adopted at political levels or promoted for being adopted.

Components and features of governance

As discussed above, groundwater governance has four broad components: actors, their roles and modes of interaction; legal and institutional frameworks; policies and plans and their development and implementation; and information, knowledge and science. This section sets out the analytical framework in preparation for the detailed assessment in Sections 3.4 to 3.7 below.

Actors, their roles and modes of interaction

> *Actors are of diverse character but all are driven by their own interests and pursue goals within the incentive structure*

Actors may range from individuals to small or large organizations (either belonging to the government or not — like NGO's, private companies, co-operatives, pressure groups, etc.). Governance is shaped by actors (which categories can be identified? how are they organized? etc.) and how they behave and interact. The incentive structure — institutions, prices — sets the framework within which each actor pursues goals. In this, each actor is driven by individual interest, the shared interest of a group or by assigned tasks and mandate.

> *The governance challenge is to include all relevant actors in a common endeavour within a conducive incentive structure in pursuit of agreed common goals*

Actors may have conflicting or mutually incompatible objectives and consequently the degree of co-operation in governance may vary considerably. Good groundwater governance requires the inclusion of all relevant actors in a common endeavour within a conducive incentive structure to align all behavior and action with agreed common goals.

Legal and institutional frameworks

> *Laws set out the norms to be followed and the institutional and regulatory framework applies these norms*

Alignment of groundwater governance actors with policies and plans is pursued — among others — through legally binding norms setting behavioral boundaries in general, and within an institutional framework that delineates the roles and responsibilities of institutional actors in particular. Legal norms are typically laid down in formal laws — approved by the mandated parliaments or political leaders — and the application of laws is spelled out in the corresponding institutional and regulatory arrangements based on the laws.

Groundwater law thus typically covers the role of the state, ownership and use rights, the regulatory framework and the institutional set up and mandates

Regarding groundwater, typical themes addressed by the legal frameworks are groundwater ownership and user rights, protection of groundwater from pollution, the role of the state in regulating groundwater use and protection, the mandates of dedicated organizations and the rights and obligations of the different actors. Administration, performance monitoring, and eventual enforcement, of the laws are important facets of legal and institutional frameworks for groundwater governance in general, and for the implementation of policies and of action-oriented management plans in particular.

In some areas, customary law also sets norms

Particularly in rural areas with long traditions of water resource management, customary law — i.e., the body of un-written norms borne out of long-standing practice — may be as important as statute law and equally or even more binding on the members of the community observing them. The degree to which customary law can cope with the volume and intensity of demand for groundwater and aquifer services needs to be judged carefully avoid exploitation and depletion of these natural resources.

Policies and plans

Policies define societal objectives and set goals and boundary conditions to be implemented through plans

Policies define objectives and principles. At some point, policy driven planning and management of groundwater and aquifer bodies is likely to become an imperative where standard legal and customary provisions prove inadequate. The degree to which they provide the agreed agenda set goals and boundary conditions for action-oriented management plans should be a measure of the governance arrangements. Examples are given in (Table 3.1), but a fine line has to be judged as to when such planning is pro-active rather than re-active with the understanding that the cost of reactive measures are likely to much more expensive than a proactive approach.

Information, knowledge and science

Information, knowledge and science are essential to groundwater management

Policies and management plans need to be based on understanding of conditions in the area concerned. Given the unseen nature of the resource, **awareness** amongst stakeholders is vital. Assessment and monitoring are the only ways to make groundwater fully comprehensible to stakeholders and the only way to provide needed information to those in charge of management.

Information and knowledge need to cover not only technical aspects but also socio-economic and environmental considerations as well as the multiple linkages to other sectors

The mentioned information and knowledge should be related not only to the groundwater systems proper and their time-dependent variables, but also to the abstraction and use of groundwater (including its social, economic and environmental impacts), related ecosystems and other relevant interdependencies.

Governance thus requires good information and science provided through dedicated information services — and dissemination amongst all concerned stakeholders

The interpretation and analysis of all this information — to be fed into policy formulation and planning — should be done according to up-to-date scientific principles and methods. Information and awareness programmes should ensure that the information is disseminated among the stakeholders to the extent needed. Good governance requires that dedicated information services are in place.

3.2 Region- and country-specific settings for groundwater governance and management

Each country or groundwater area can be categorized in one of three stages of groundwater development and management

Each region and country has its own specific setting that explains to a large extent the local motivation and focus for groundwater governance and management, as well as the approaches chosen and the progress achieved to date. This setting has a diversity of dimensions, defined by physical, historical, socio-economic, cultural and political factors. It is not static but evolves over time, but not everywhere at the same pace. Countries (or areas within countries) have different histories with regard to groundwater resources development and management, but their evolution can generally be categorized in three stages:

- **Pre-management stage** – with groundwater being abstracted for local use without people having any notion that its control, management or protection were possible or desirable.
- **Initial management stage** — in response to emerging problems steps towards management or protection are taken, according to the problems on an essentially 'single-issue oriented' basis.
- **Advanced management stage** — some countries have subsequently moved towards more comprehensive and integrated approaches to groundwater administration and protection.

Consequently, some countries are in a pre-management stage regarding groundwater, whereas others are in an initial or even in an advanced management stage. The transition from one stage to the next one is gradual and accompanied by a change in focus, improved governance and more intensive groundwater management activity.

In the past, traditional governance and management practices emerged in many countries to manage water collaboratively

Groundwater management and governance emerge in response to perceived needs and aspirations. Early examples in history are the water boards in The Netherlands, the Baillages in France, the Water Court of Valencia in Spain, and the communities sharing a *qanat* in Iran or other forms of traditional collaborative management in the Middle East. The water boards in The Netherlands were established many centuries ago with the original purpose of defending the land against flooding and controlling groundwater levels to make and keep the land suitable for habitation and agriculture. The water court in Valencia was established in the 8th century to solve disputes between farmers on water, usually on allocation of scarce water resources. The organization of Iranian communities sharing a qanat date from time immemorial and have over many centuries developed and maintained cooperative behavior that results in optimal use and protection of their shared groundwater resource and the technical infrastructure to tap it.

Many factors have driven groundwater use — securing domestic supplies, poverty reduction, the search for food security — but often, particularly in arid areas, pursuit of these objectives has contributed to excessive abstraction and consequent depletion

Until today, we can observe groundwater management and governance to be driven by a great diversity of needs, aspirations, aims and threats. First of all, reducing the number of people without access to safe water supplies is a major concern in many poor areas in the world, in particular in rural areas in Sub-Saharan Africa; this is reflected by a focus of the local groundwater community on projects for improving domestic water supply. Partly in the same areas, poverty or food insecurity may be important drivers behind systematic groundwater development programmes. Elsewhere, in the Arab region and other arid and semi-arid zones of the world, severe water stress and ground¬water depletion are the main issues in groundwater management. Groundwater abstraction has increased explosively in most of these zones, as a result of demographic, socio-economic and technological development. The depletion of groundwater in the Arab region has had significant socioeconomic and environmental impacts and costs (Box 3.1). In much of the region, this is depletion has been greatly encouraged by the extremely low energy costs.

As demand rises rapidly, trade-offs and mitigation options to protect the resource are needed

The dilemma posed by these challenges is how to strike a balance between meeting crucial water demands and preventing exhaustion of the groundwater resource. Mitigation options may be identified and implemented in the form of augmenting the groundwater resources or using existing resources more efficiently. Intensive groundwater abstraction may also result in environmental damage, even in humid areas, e.g. degradation of wet ecosystems and land subsidence. The latter is affecting many cities in the world, including Tokyo, Bangkok, Jakarta, Tianjin, Shanghai, Calcutta, Venice, Mexico city and San Francisco. In virtually all countries with quickly expanding population, rapid economic development and resulting changes in living standard, in particular in Asia, explosive water demands result in a strong increase in groundwater abstraction.

Box 3.1

Impacts of Groundwater Depletion in Bahrain

Over the past four decades, heavy reliance on groundwater to meet Bahrain's escalating water demands has resulted in groundwater abstraction rates exceeding the aquifer safe yield since the 1970s. This prolonged groundwater overexploitation has led to severe deterioration of water quality due to seawater intrusion and saltwater upflow from the underlying strata, as well as the complete loss of all the naturally flowing springs. Currently, most of the aquifers in Bahrain have been lost to salinization.

When evaluating the impact of groundwater depletion on society, two key issues are typically considered: the **level of reliance on groundwater** and the **cost of providing replacement supplies from another source**. In addition, in the case of Bahrein, other considerations are also at stake: groundwater in Bahrain has a scarcity value and the **opportunity cost** for alternative or competing uses must be incorporated, as well as its functional value in **maintaining the ecosystem** and its value as a **strategic water source in emergencies**.

The cost of providing replacement supplies from another source is enormously high as it would require production of about 110 Mcm/yr of seawater desalination and/or treated wastewater (depending on its intended use) at an estimated cost of $160 million per year.

Furthermore, the loss of groundwater significant impacts on the country's socio-economic development as well as on the environment. The **deterioration of groundwater quality** has had an impact as traditional agricultural areas have been abandoned due to the loss of their productivity. Moreover, **groundwater depletion** has had an impact on the environment, **wetlands and biodiversity** in Bahrain. The loss of natural springs and the drying out of their surrounding environment has caused destruction of flora and fauna habitats, compromised ecosystem services and functions, loss of the historical and cultural value of those areas and their potential for tourism, as well as their in situ value as a strategic reserve for emergencies.

Al Zubari, 2013

In many locations, pollution is the biggest issue, some of it a legacy issue from past industry or mining

Almost everywhere across the world, groundwater quality is at risk of getting degraded either by seawater intrusion (in coastal zones) or by anthropogenic pollution by a large variety of contaminants, in urban, industrial and mining zones as well as in agricultural areas. Pollution control is perceived as the principal groundwater management issue in most of the countries of Europe and in the United States; apart from current pollution threats, many of these countries experience widespread and serious groundwater quality impairment from the legacy of industrial pollution and the impacts of mining. Recovering from this legacy may present specific governance and management challenges where the activity has ceased and the enterprise which caused the impairment no longer exists, making the ‘polluter pays’ principle very difficult to implement. The sometimes very high and prolonged costs of remediation may need to be borne by the broader society from general taxation. In the US, comprehensive environmental legislation led to the ‘Superfund’ approach to funding the remediation of legacy pollution of groundwater, but such large sums of money and the necessary expertise are unlikely to be available elsewhere.

Shallow aquifers are the first to be exploited — and the most vulnerable

Originally, groundwater exploitation has in almost all parts of the world largely targeted the first aquifer encountered below ground surface, often unconfined alluvial aquifers, hence highly vulnerable. In densely populated areas, e.g. in large parts of Europe, many of these shallow aquifers have become degraded by pollution, beyond any possible rehabilitation. Obviously, groundwater management approaches and groundwater governance provisions vary from country to country, according to the key issues and main challenges perceived.

The political setting is also an important determinant of governance, with strong centralized power dictating a more top-down approach, and more pluralistic systems encouraging a greater measure of stakeholder participation

But there are more factors shaping groundwater governance. Among these are the political and economic settings. In the UNECE region, the long established and ‘mature’ democracies of relatively wealthy western and northern Europe and North America are contrasting in this respect with the new countries of the Balkan Region, the Caucasus and Central Asia experiencing social and economic transition. Elsewhere, political systems and economic conditions are equally variable. Strongly centralised power tends to be an obstacle to active stakeholder participation at all levels, whereas multi-party democracies with electoral processes embracing varying forms of proportional voting facilitate the representation of smaller political parties. Thus, Green Party politicians have become prominent first in parliament and then in government in some countries, and even more widely at local government and municipal levels. This has obliged established political parties to become more environmentally sensitive in their own policies and commitments. Higher standards of living, increased leisure time and the desire for outdoor activities have contributed to greater public environmental awareness and strengthened NGOs working in nature and conservation (Chilton and Smidt, 2013).

Movements such as the Arab spring may provide an opportunity for more participatory approaches — but change is likely to proceed step-by-step

The recent political changes in the Arab states since 2010, referred to as the 'Arab Spring', might result in significant changes in the political environment in the corresponding countries; these changes, in turn, may provide a window of opportunity for improving groundwater governance. Whatever will happen, it is expected that transformations to new governance structures and practices will take considerable time and efforts. Under current financial and economic conditions, it is difficult to implement changes that increase the burden of citizens; therefore, only 'piecemeal introduction' of improving groundwater governance seems to be a viable pathway (Zubari, 2013).

Generally, although the drivers of change are various and location-specific, countries in the earlier management stages focus on increasing supply whereas the more advanced countries focus on sustainability and environmental issues

History, tradition, culture, preferences for groundwater as a source of water supply and the existence or absence of supranational bodies (such as the EU in Europe, or of inter-governmental coordination institutions such as the OAS in the Americas and the AMCOW in Africa) are additional factors that contribute to the diversity of the state of groundwater management and governance around the world. It is too simplistic to assume that all countries will follow the same path. Nevertheless, it can be observed that groundwater management and governance tend to focus on water scarcity problems and on building physical water infrastructure in developing countries or countries in economic transition, while many of the OECD countries have opted for more attention to sustainability issues and control of environmental impacts.

Table 3.1 summarizes some of the differences between the five regions with regard to groundwater governance related features — as articulated in the regional consultations. The ratings are summary and may conceal large differences between countries within each region. Consequently, the table shows general tendencies and may not be indicative of the conditions in any individual country.

Table 3.1

Some perceived differences between regions regarding groundwater governance

	Region				
	LAC Latin America & Caribbean	**SSA** Sub-Saharan Africa	**A&P** Asia & the Pacific	**AR** Arab Region	**UNECE** UNECE Region
Predominant stage of groundwater management					
Pre-development		x			
Initial management	x		x	x	
Advanced management					x
Society's dependence on groundwater					
Moderate	x				
High		x	x		x
Very high				x	
Key management issues currently driving governance					
Improving domestic/public water supply	xx	xxx	xx	xx	x
Improving sanitation and wastewater treatment	xx	xx	xx	xx	x
Groundwater use for irrigation	x	x	xxx	xx	x
Impact of rapid urbanization	xx	x	xxx	x	x
Groundwater pollution from agricultural land-use	xx	x	xx	x	xxx
Impact of industrial activities	xx	x	xx	x	xx
Environmental control and ecosystem protection	xx	x	xx	xx	xxx
Constraints to good groundwater governance					
Lack of awareness and knowledge of groundwater	xx	xxx	xx	xxx	x
Insufficient political commitment	xx	xxx	xx	xx	x
Poverty and lack of funds	xx	xxx	xx	x	x
Weak institutions	xx	xxx	xx	xxx	x

Some 'new generation' issues are also emerging, related to past and present sub-surface activities — 'fracking', carbon storage, mining, transport and urban development

Beyond the collective perception of the regional consultations it is also possible to identify more management issues that have local and global significance for groundwater governance. Hydraulic fracturing and carbon storage are issues that are seeing global resonance. Less apparent is the accumulation of many groundwater externalities produced by new mining development and the legacy of centuries of mining and de-watering activities which are letting groundwater levels recover into stores of acid drainage and mine waste. The aggregate impact of excavation of the underground space for tunnelling and urban development should also not be ignored. Urban planning in particular is either unaware of the scope and intensity of groundwater problems generated by construction and drainage modification or simply trying to catch up with urgent remedial measures to counter subsidence and prevent further loss of aquifer functions upon which urban areas depend. Addressing these relatively new management issues will undoubtedly reveal new constraints related as much to technical gaps in remediation or prevention capacities as to the political economy of land-use and planning regulations.

There have been improvements in governance in some countries, but generally the 'governance gap' is widening

While examples of progress in advancing groundwater governance is undisputed (such as the 'contrat de nappe', processes initiated in Morocco) widening gaps in governance provision are all too apparent. To this extent, strengthening groundwater governance is "work-in-progress throughout the world" (Shah, 2009) and given both the limited awareness related to groundwater and the complexity of the challenges to be addressed, it is not surprising that the diagnostic reports of the five regional consultations indicate that the state of groundwater governance is still rather poor in many countries. The next section will give some clarification.

3.3 General policy responses

*Examples from the regional diagnostics show good practice on each of the components of governance — but there are few examples of good practice on **all** components together*

Despite the apparent lag in effecting 'good' groundwater governance, numerous instances of significant progress towards sustainable groundwater management are being reported worldwide, which are witness to some strengthening of governance provisions.[6] Collectively these examples cover the components of groundwater governance but individually most deal with only some of the components.

Good practice examples provide illustrations that may be adapted to different country and area situations

International support, policy guidance and political agendas variously have catalyzed these attempts to strengthen governance and improve management practices. While in all cases there remains some questions about the long-term sustainability of these attempts, and to what extent and where they might be replicable, their analysis provides valuable insights on the way forward in different hydrogeologic, socioeconomic and politico-institutional settings.

International policy initiatives have played an important facilitating role — and aligning incentives has been a particular factor in success

The UN-MDGs have produced a significant impact on groundwater supply provision and protection in the developing world, and the EU-WFD has acted as an excellent catalyst for more systematic groundwater quality protection in the European Union.

6 Table 3.1 shows examples selected from the five regional diagnostic reports on groundwater governance; for more detailed information on each example mentioned, reference should be made to the corresponding reports (Tujchneider, 2013; Zubari, 2013; Kataoka & Shivakoti, 2013; Braune & Adams, 2013; Chilton & Smidt, 2014). Numerous examples can be found in publications prepared by GW-MATE for the World Bank and by IWMI, in reports captured on TheWaterChannel's web portal and in some text books (e.g. Shah, 2009; Margat and Van der Gun, 2013).

To meet the major challenge of divergence of stakeholder objectives requires an understanding of the social dynamics — and of the incentive structure within which stakeholders operate

One of the major challenges of groundwater governance is the large number and considerable diversity of stakeholders that need to collaborate towards a common goal — and getting stakeholders with divergent objectives to cooperate requires understanding of the underlying social dynamics of human behavior and of the incentive structure within which the actors operate. As stated by Shah (2009): "although the (physico-chemical) science of how groundwater behaves is well developed, the social science of how its users behave is still in the making".

Where management goals have aligned with private aspirations and where there are incentives to cooperate, outcomes have been good

A key lesson from the Project is that it is easier to achieve successful outcomes if **management goals align with private aspirations** (e.g. for more secure water-supply) and if the **incentive structure provides incentives to cooperate** (e.g. if management measures include improvements in physical water-sector infrastructure).

Innovations in incorporating the 'precautionary principle' into managing groundwater pollution zones and taking a risk-based approach to pollution have opened up new pathways to water quality management

An important general policy response is the widespread building of the precautionary principle into groundwater protection policies. One of the dominant features of applied hydrogeological research and practice over the past three decades has been the development of approaches to mapping at aquifer scale the vulnerability of groundwater to pollution from activities at the surface as an aid to land use planning (Custodio, 2012). This has been matched at a more local scale by the definition of groundwater protection zones around vital public supplies and the introduction of progressively stronger controls of potentially polluting activities in the zones closest to the borehole, well or spring.
Of course, the presence of a potentially hazardous source does not necessarily lead to pollution, and there has been significant associated development of groundwater practice related to pollution risk assessment. This attempts to characterise both the nature of the pollution loading and the transport and attenuation properties of the pathway through the soil and unsaturated zone to groundwater (GW Mate 2002-2006). Much of the approach to implementation of the EU Water Framework and Groundwater Directives requires a risk-based approach using the source-pathway-receptor concept.

3.4 Actors: their roles and modes of interaction

Categories of actors

There are numerous actors in groundwater, both public and private, some local, some national, some international

There is a diversity of actors or potential actors in groundwater governance, belonging to the public sector, the private sector or society in general. At the national and local levels they include government organizations responsible for (ground)water management, environmental management or related tasks; public or private water utilities (water supply and sewerage agencies or companies); groundwater users in the domestic, agricultural or industrial sector (ranging from very large to *'de minimis'* uses); government representatives of the different water use sectors; water user associations; NGOs; industry, the mining sector, the construction sector and other private sectors with a stake in the subsurface or influencing subsurface conditions; academic institutions, research and development organizations, consultants and other representatives of science and technology; schools and mass media. Several of the most important stakeholders are both users and actual or potential polluters of groundwater. Stakeholders at the international level include bodies established for regional cooperation between governments; river basin organizations; entities dedicated to transboundary aquifer management; multi-nationals; and international cooperation partners such as UN agencies, other donors, international NGOs and scientific associations.

Many actors have divergent or conflicting objectives and roles, and cooperation is limited in almost all countries and areas

In principle each of these actors or potential actors has his or her own specific stakes, objectives and roles (see Table 3.2). The complexity inherent in the large number and diversity of stakeholders, and the fact that their interests may be partly conflicting explain why smooth and balanced cooperation in groundwater governance is not automatically forthcoming, but has to be orchestrated. In fact, no area in the world has achieved full cooperation on groundwater. On the contrary, many areas exist where only few actors are actively involved in groundwater governance and where many potential actors are interacting negatively rather than aligning their actions and behavior to the common good.

Table 3.2

Potential range of interests and activities of groundwater stakeholders beyond government institutions

Sector	Water-use classes	Polluting processes	Other categories
Rural	Domestic supply Livestock rearing Subsistence agriculture Commercial irrigation	Household waste disposal Farmyard drainage Intensive cropping Wastewater irrigation	Drilling contractors Educational establishments Professional associations Journalists/mass media
Urban	Water utilities Private supply	Urban wastewater disposal/reuse Municipal landfills	
Industry & Mining	Self-supplied companies	Drainage/wastewater discharge Solid waste disposal Chemical/oil storage facilities	
Tourism	Hotels and campsites	Wastewater discharge Solid waste disposal	
Environment**	River/wetland ecosystems coastal lagoons		

* Beyond local water resource, land planning and environmental protection agencies *(GW-MATE, 2002-2006)*

** Usually represented by some form of NGO and/or local authority

Geographic variation of the involvement and roles of different actors

Groundwater governance and management are typically public responsibilities in law, although how this translates into practice — and the degrees of stakeholder participation — vary considerably

Typically, groundwater management and governance are legally public sector responsibilities. The way this mandate is translated into an institutional set-up and into action and cooperation varies widely. Water users and other non-government stakeholders play a highly variable role. In some cases they are actively involved in supporting and promoting improved groundwater governance and management. In many countries, however, they concentrate on their own objectives and interests, with little or no intention of cooperating with the government and other stakeholders. In strongly centralised and controlled political systems, civil society and non-government organizations may have little opportunity to become involved or be actively discouraged from doing so.

*In **Latin America and the Caribbean**, groundwater issues are generally handled by ministries and subordinated public agencies, but with quite some fragmentation of tasks*

Water supply and sanitation services are provided partly by public and partly by private agencies. In some cases such private partners show good performance and comply with government rules (Uruguay), while in other cases the privatization of water and sanitation services has not been successful, in some cases even to the point that the state had to take over again (e.g. the Cochabamba case in Bolivia).

*Within the **UNECE Region**, there is a wide range of approaches, ranging from essentially privatized approaches (Texas, parts of Canada) to full state control. Countries of the EU have advanced governance focussed on protection of the resource and of the environment*

The UNECE region shows large variations in the role played by the governments. At one end of the spectrum, e.g. in Texas (USA) and the Canadian provinces of Ontario and Prince Edward Island, private ownership and development of resources, including groundwater, are protected and encouraged and the state has a minimal role in regulating processes between stakeholders. At the other end, e.g. in Israel, Turkey and the countries of Central Asia, groundwater is considered as a public property resource, mainly controlled and managed by public authorities. Somewhere between these two extremes are the countries of the European Union which, over the past thirty years, have been guided by the environmental legislation of the European Union, in particular by the Water Framework Directive (WFD), which has been a real ‘game-changer’.

*In **Arab countries**, water management and related institutions are relatively advanced, although groundwater regulation is generally weak; levels of stakeholder participation vary, with large scale irrigation remaining largely 'top down', but smaller groundwater schemes — both traditional and modern — have quite high levels of participation*

In the countries of the Arab region, in addition to the water supply agencies several governmental institutions have a role in groundwater governance, including those dedicated to agriculture, irrigation or health, and in some cases municipalities are also involved. In some countries (e.g., Algeria, Morocco, Yemen, Sudan, and Egypt) representatives of local users and user associations have a role in water governance, with only one country (Tunisia) having educational and research institutes involved. However, the majority of groundwater institutions are inadequate, or they need support in capacity strengthening and building, especially training of staff, availability of material and budgetary support. Moreover, most of these institutions have not yet developed strong management and monitoring systems. It should be noted that water governance in many Arab states has traditionally been at the local level. Oasis and Aflaj communities in many areas in the Arab region continue to manage the allocation of water between individuals, and the quality is maintained through ownership responsibilities of the resource (Zekri and Al-Murshudi, 2006). In the twentieth century, the big drive towards supply development and large irrigated perimeters caused new institutional structures to emerge for managing the nations' water resources. Since then and until recently, water management in the Arab region has been highly centralized and for the most part managed at the national level with little local stakeholder and civil society participation, resulting in governance structures which have been viewed as ineffective and fragmented (Al Zubari, 2013).

*In the S**ub-Saharan Africa Region**, the priority for developing groundwater is high; attempts to implement IWRM are slow to bear fruit; village water supply is often a collaborative effort but much development is by individuals and groups outside the regulatory framework*

In Sub-Saharan Africa water governance structures are rolled out in all countries, but most action has remained at the national level, with the present focus on the establishment of river basin and catchment organizations as a key institution in integrated water resources management (IWRM), as promoted by the AMCOW. Groundwater is still poorly integrated into the IWRM processes of resource allocation, protection and conservation and its focus has remained with resource infrastructure development on a largely ad hoc basis. Groundwater governance has remained at national level and in government regional offices, with virtually no direct stakeholder participation. On the other hand, decentralization of water supply and sanitation has brought a major groundwater supply activity to the local government at district level, undertaken by new players with very limited capacity for sustainable utilization of groundwater resources and poor links to the government resource management function. In addition, in several countries there are village level water committees, but usually they are poorly integrated into the higher levels and in need of empowerment and a more pronounced role for women. There is a growing recognition at the highest water-political level in some countries of the strategic importance of groundwater towards the regional development objectives. This presents for international cooperation partners, who are playing a critical role at the moment, a major opportunity to address the groundwater governance function strategically with their African counterparts.

The **Asia** *and the* **Pacific Region** *again paints a mixed picture with most countries having agencies with IWRM responsibility and levels of participation varying from very little in China to quite high levels in India, Indonesia and elsewhere*

In the Asia and the Pacific region, groundwater is sometimes neglected in the institutional arrangements made for effective water governance, in spite of the fact that many countries have conducted a process of water sector reform. Water resources management is governed by dedicated ministries in China and in the states of India, under which responsible sections or institutes for groundwater have been established. Countries such as Laos, Thailand and Vietnam, on the other hand, have consolidated water resource management departments responsible for both quality and quantity, which used to be handled by separate ministries, under natural resource and environmental management, though public water supply services still operate under other line ministries. In the case of Thailand and Vietnam, the groundwater department under the Ministry of Natural Resource and Environment has primary responsibility for governing groundwater and coordinating with other related departments as necessary. Conversely, in the Philippines sixteen authorities related to groundwater management exist, which has led to overlapping and fragmented responsibilities (Tabios, 2012). Malaysia does not have a specific groundwater management organization, and different line ministries are in charge of groundwater management. (Suratman, 2012).

At the local level, both decentralized government and local stakeholder organizations play a role, with varying results

The role of the local government is crucial in ensuring effective groundwater governance, but such roles vary in terms of level of involvement in groundwater management due to differences in administrative systems between countries and also the actual capacity of the local governments. In rural areas, the local community often plays a central role. Water user groups or groups of farmers play a critical role in community groundwater management projects practiced in India (e.g. in Andhra Pradesh). Nevertheless, the mere existence of organized stakeholder groups is not a guarantee for successful stakeholder participation, as is shown by the disappointing results of many water users associations that were created in India in the framework of Participatory Irrigation Management (Shah, 2009).

Capacity, transparency and accountability of actors

> *Low awareness of the importance of groundwater and of the issues related to it has translated in many developing countries into absence of political commitment, low budgets and consequent low management capacity*

In many parts of the world the capacity of key groundwater governance actors is relatively low. This has probably a lot to do with perception, usually rooted in poor understanding of groundwater and its context. At the level of governments, there is often little awareness of the importance of groundwater and the need to manage it properly, which makes activities related to the invisible ground¬water with its long response times politically unrewarding. As a result, groundwater is low on the political agenda in many countries, which translates into very limited funding for government agencies in charge of groundwater assessment, monitoring and management. Consequently, such agencies are in many cases understaffed and provided with very modest financial means. In some countries, the limited government activities related to assessing, monitoring and analyzing are partly compensated by such programmes at academic institutions.

> *In more developed countries, by contrast, there is excellent capacity and expertise*

Quite a number of countries in the world have an impressive history related to hydrogeology, groundwater development and/or groundwater management, which has resulted in the existence of high-capacity government agencies and scientific institutes related to groundwater. Notable examples are Australia, Brazil, Canada, China, the Czech Republic, France, Germany, Hungary, India, Japan, the Netherlands, Norway, Poland, Romania, Russia, Serbia, South Africa, Spain, Sweden, the United Kingdom and the United States of America. In several other countries, governments — motivated by growing awareness on groundwater — are strengthening their groundwater institutions, often with the support of international cooperation partners or donors.

At the local level, individual stakeholders have typically managed the resource in isolation, but emerging problems have stimulated the establishment of local interest groups like groundwater associations

At the level of self-supplying groundwater users, the traditional perception is often that abstracting groundwater is a private affair that does not require any coordination or cooperation with third parties, except when there is a need for external technical or financial support to establish and run the infrastructure. Hence, such stakeholders usually do not have well-developed institutional mechanisms to get their voice heard. But there are positive exceptions. Recently, local community stakeholders and user associations have been established in Arab countries like Egypt, Jordan, Libya, Morocco, Oman, Tunisia and Yemen. In Sub-Saharan Africa, examples of such local groups are the village development committees and village water point committees in Malawi and the water user associations or groups in Tanzania. These local set-ups contribute to empowering the local ground¬water users as actors in groundwater governance.

Large scale water supply providers and supporting industries generally have the resources and capacity to manage groundwater correctly but the small scale providers common in Africa and parts of Asia may not be so well equipped

Water supply agencies or companies and the supporting services and industries (drilling, pumps, etc.) are in a more comfortable position. Their role is generally better understood and undisputed, and the products and services they provide generate funds, partly on the basis of market processes, that enable them to build and maintain their capacities. A positive factor in this respect is the fact that cost recovery for services in a socially affordable manner has become generally accepted, in spite of the old notion of water as a 'free commodity'. Most often overlooked are the small and often informal enterprises that fill the demand for water and sanitation services from households beyond the reach of public water supply delivery. Alternative service providers (ASPs) provide them with access to water through private supplies such as wells, public stand posts, water kiosks, informal distribution networks, tankers and small-scale vendors. In Sub-Saharan Africa they can account for up to 60 or 70% of market share in some countries (AfDB, 2008) and similar services are also common in Asian countries such as India and Nepal.

Past reluctance of government agencies to demonstrate transparency and accountability is being eroded in some countries as stakeholders begin to participate more

Transparency and **accountability** have never been priorities in government agencies that perceived groundwater resources management as a top-down activity, implemented by the government and focusing on the enforcement of laws and regulations. Progressive understanding of the advantages of decentralizing groundwater management and of the need to involve multiple stakeholders opens a window of opportunity for improving transparency and accountability. Closer interaction between government agencies and local stakeholders results in stronger demands from the latter to be informed on intended interventions, to be heard and to have access to information on the measures taken and their impacts. Increased transparency and accountability can be observed in countries that have intensified stakeholder involvement in groundwater management, or that carry out groundwater activities with commitment to interstate or international frameworks, such as the US Superfund, the EU Water Framework Directive and its Groundwater Daughter Directive, the Millennium Development Goals, or GEF funded projects.

Conflicts, coordination, cooperation and partnerships

Many factors can drive competition and conflict over groundwater…

The open access and common property nature of groundwater, the finiteness of the groundwater resources, groundwater vulnerability, incompatible interests in groundwater between people (including groundwater users and others) and the linkages of groundwater with ecosystems and the environment all are potential causes of conflicts. As a matter of fact, examples can be observed in many parts of the world: wells that have gone dry because of intensive pumping from neighboring wells; aquifers becoming exhausted by uncoordinated competitive pumping for different purposes; groundwater pollution as a result of certain land use practices, accidents or inadequate waste water disposal practices; land subsidence due to groundwater abstraction in zones with compressible sediments near the surface; degeneration of springs, base flows and wet ecosystems.

Resolving conflicts requires coordination of actors behind rules, cooperation over management, and a partnership between public and private actors

It is beyond the power of individuals to prevent such conflicts and the problems they cause; this requires effective **coordination** of the individual behavior of the main actors, in such a way that negative impacts are minimized. This coordination can partly be produced by creating incentives for a desired behavior and by enforcement of regulations based on dedicated groundwater and environmental laws. Many countries in the world have developed and implemented such regulations. But **cooperation** between the principal stakeholders is needed under a groundwater governance framework to promote good compliance with these regulations, to improve human behavior with respect to groundwater beyond what incentives and regulations do, and to prevent the implementation of projects in the groundwater domain that counteract each other. Stakeholders should feel a shared responsibility for the use and protection of the groundwater resources in their region, in an agreed way that is optimally aligned to the common good. A prerequisite is that mutual trust and respect are built between government agencies and local stakeholders.

A main challenge remains to get local stakeholders actively involved in groundwater management and governance

In the majority of the countries the level of local stakeholders participation across the whole groundwater management process is still very low, if not absent. The Arab region's recent experience shows that some of the water users associations (WUAs) have been established through a bottom-up consultative approach, where authorities have conferred with ordinary water users. This helps not only to increase their participation, but also to improve the welfare of farmers and develop irrigation and drainage by providing an alternative to the monopoly of public utilities (Abou-Hadid, 2010), thus enhancing their empowerment. Farmers should play an important role in groundwater management, but significant effort may be required to enable this to happen (Box 3.2). In some countries of Africa and Asia, local stakeholders are successfully involved in establishing physical infrastructure for groundwater development (well and water supply infrastructure) or managed aquifer recharge (sand dams and other groundwater recharge enhancement works). Often this is in cooperation with NGOs or international cooperation partners.

Partnerships with government and with academia and the private sector can also contribute to good governance

Apart from more or less formal involvement of end-users of groundwater, there are other *partnerships* between actors. Within the government, structural cooperation between different ministries can be mentioned and also between different government levels, ranging from national to local, which in many countries still has to be achieved. Most countries have also partnerships between government agencies involved in groundwater and academia, and also with the local private sector such as drilling companies and consultants.

Box 3.2

Farmer Management of Groundwater in Andhra-Pradesh

Community participation is a key feature of the success of groundwater management, especially in the context of groundwater use by small users. The Andhra Pradesh Farmer-Managed Groundwater System Project (APFAMGS) is a case in point. This scheme involves raising the capacity of farmers so that they can manage their own systems, and includes education in hydrogeology and groundwater monitoring. The governing principles of participatory management include equitable rights, long-term commitment, community management embracing all users, and reliable baseline data. No financial incentives have been introduced under the project. Convincing farmers that reduction of water use can bring future benefits is one of the most difficult tasks in such a project. By providing the means to raise productivity and income per drop, APFAMGS succeeded in convincing farmers to reduce groundwater use.

Kataoka and Shivakoti, 2013; from World Bank, 2010

International partners can also contribute much to the development of good governance and management

Partnerships between national governments and international cooperation partners are particularly important in Africa, Latin America and the Caribbean and Asia. These partnerships produce transfer and exchange of knowledge and constitute in many cases also important sources of funding. Regional institutions like the African Ministers' Council on Water (AMCOW) and the African Network for Basin Organizations (ANBO) and sub-regional ones like the SADC Water Sector are completely reliant on support by international cooperation partners. These partners include geological surveys, bilateral cooperation funding agencies, and multilateral agencies such as UN agencies, the World Bank and GEF. These partnerships are complemented by groundwater related professional organizations and networks.

Cooperation with international companies can bring knowledge and experience and can contribute to better alignment of programmes

Public-private partnerships with large international companies as the private partner are still relatively rare. Developing such partnerships may result in great benefits for the groundwater sector, in the first place because there is a large potential to share information and knowledge on the subsurface and on groundwater, and secondly the partnerships may lead to better alignment between the activities of the governments and the large international companies.

3.5 Legal frameworks

Customary law related to groundwater

Customary law has been applied to groundwater for generations and it is still significant — but only for small scale abstractions in rural areas of developing countries...

Long before any formal laws were formulated, domestic customary law related to groundwater developed in many parts of the world, according to the specific local conditions and needs. For instance, most Arab countries had developed 'community water use rights' for irrigation, mainly applied to large water sources such as natural springs, hand dug artesian wells and underground canal systems (qanats or aflaj). More widespread, however, is the customary principle known as 'rule of capture'. According to this principle, groundwater is the property of the landowner or at least the landowner has an exclusive right to abstract and use groundwater under his land as much as he wishes and for any purpose he wants, without being liable for any damages caused to his neighbors or to society at large. In old times, the technology of the hand-dug well and extraction by man or beast limited damage to the aquifer or to the environment in general. With the advent of the powerful tubewell and big pumps, this link between land ownership and groundwater use rights has persisted in many parts of the world and it still remains so in the perception of numerous individuals who abstract groundwater, even though the technology — and the incentive structure — are now driving wholesale depletion. However, as a result of litigation, landowners nowadays can in many countries no longer use and abuse their ownership rights in groundwater with impunity. The role of customary law in groundwater governance is still significant in the rural areas of many developing countries as regards local abstraction for domestic use, subsistence agriculture and livestock rearing. It has, however, become largely irrelevant as an instrument of governance where groundwater is abstracted for large scale water supply or commercial use.

... and the erstwhile application of customary law to groundwater protection has been largely overtaken by the massive scale of abstractions

Customary practices also evolved locally for the protection against pollution of groundwater sources used for household and religious purposes. The role of such practices is now marginal in the context of vastly increased abstractions.

Formal domestic laws and regulations relevant to groundwater

Laws on groundwater — and other laws affecting groundwater — are found in almost all countries

Virtually all countries of the world have formal laws that in one way or another address groundwater. In addition, they usually have domestic laws on other policy domains (e.g. agriculture, land use planning, environmental management, mining, etc.) that are also relevant to groundwater, even if they do not mention it explicitly. Federal nations often have legislation both at the national and the highest sub-national level. This explains why in the US and other federal nations there may be considerable variations in legislation between the individual states.

*Law typically covers **ownership and use rights**, **protection from pollution**, and **institutional arrangements for management and regulation***

Important subjects in domestic laws addressing groundwater are: (i) groundwater ownership; (ii) the abstraction and utilization of groundwater based on user rights; (iii) the protection of groundwater from man-made pollution; and (iv) the assignment of government roles and mandates related to groundwater quantity and quality.

*The explosive growth of groundwater use and the resulting problems have prompted many countries to redefine **groundwater ownership and use rights***

Defining *groundwater ownership and user rights* is of crucial importance, because diverging perceptions on these aspects lead to incompatible action and behavior, resulting in conflicts and damage to the local communities, the water resources and the environment. As mentioned before, private groundwater ownership or user rights are predominant in customary law, while in some settings under special conditions (springs, qanats, etc.) groundwater is considered and used as a common property resource. The explosive increase of groundwater abstraction during the twentieth century and the related stronger need for managing the groundwater resources have prompted many countries to critically review *groundwater ownership and user rights* and to define the outcomes clearly in formal laws. On a global scale, this has produced tendencies towards abandoning private ownership and declaring groundwater ownership by the state, but there are large variations across the planet.

In the USA, private rights are dominant, with four sets of rules applied in different states

The US ranks among the countries where private groundwater ownership or user rights still play a strong role, although with variations from state to state. Under these private rights four main doctrines can be distinguished: the **rule of capture** (unlimited abstraction rights), the **reasonable use rule** (abstraction rights restricted by liability conditions), the **correlation rights doctrine** (in case of scarcity, abstraction entitlements proportional to size of land owned) and the **prior appropriation doctrine** (senior rights prevail over junior abstraction rights). Other countries where groundwater rights are linked to land ownership are Japan, Sri Lanka and several small island states in the Pacific. Private ownership or user rights strengthen the position of individuals and limits the power of governments to control.

In Europe, Latin America, Africa, Asia and Australia, groundwater has been declared state property, although this has triggered some legacy problems of previous rights

In most European countries groundwater has been declared to be owned by the state. This facilitates groundwater management by the government, but is sometimes not consistent with the perception and behavior of individual groundwater users. In Spain, for instance, where groundwater was declared a public good only in 1985, most wells in existence before 1985 still continue to be in the private domain. Groundwater ownership by the state has nowadays become the legal position in many other countries of the world, in Latin America (e.g. Argentina, Bolivia, Brazil, Mexico, Uruguay), in virtually all African countries and in many Asian countries (e.g. Bhutan, China, India, Israel, Kyrgyzstan, Nepal, Philippines, Taiwan,Thailand[7] , Turkey and Vietnam) and in Australia.

Responsibility for groundwater management is usually legally assigned to public agencies at the national or sub-national level, with water quality often the subject of separate legislation and assigned to a different agency

Legal assignment of the roles and mandates related to groundwater to individual government agencies is a prerequisite for an orderly and efficient development of groundwater resources management activities. In addition, this legitimizes the corresponding agencies to enforce

7 There are no laws to define property rights or ownership of groundwater, but groundwater is considered and dealt with as a public good.

regulations based upon the law (such as licensing well drilling and groundwater abstraction, restrictions on land use and handling waste or dangerous substances, sanctions in case of no-compliance, taxes as a contribution to groundwater management cost, etc.). In the past it was not uncommon to vest the overall responsibility for groundwater in a ministry at national level, either a ministry related to a water use sector (agriculture, public water supply) or a special water resources ministry or agency (separate from a specific water use sector). Nowadays, the main responsibility and mandate for groundwater quantity seems in many countries to have been shifted to the highest sub-national level (some exceptions: Israel, Azerbaijan, Yemen), while the mandate for groundwater quality (pollution control) has remained more often at the national level, under separate legislation (environmental and pollution control laws). Laws and regulations on groundwater quality are well developed in North America and Europe, but elsewhere, e.g. in Africa, relatively rare or of limited scope. Operational tasks on both groundwater quantity and quality management are usually delegated to agencies at lower administrative levels, according to the subsidiarity principle.

Regulatory systems typically allocate abstraction licences and control polluting behaviors

Regulations aiming to control groundwater quantity and quality include in the first place permit and licensing systems for well drilling and for groundwater abstraction. They have been introduced in many countries (see e.g. Box 3.3), with varying degree of effectiveness. In the better cases, sound criteria have been developed and location-specific information is required for decision-making, elsewhere the permissions are simply granted upon request. Regulations to control groundwater pollution include bans on the use of certain chemical substances; strict rules for handling manure, waste, waste water and hazardous substances; groundwater protection zones around important well fields; land use planning and imposing land use restrictions according to groundwater vulnerability or assigned land or groundwater functions. The laws oblige the nation's citizens to comply with the regulations and to pay — if required — management fees in proportion to the volumes of groundwater abstracted or to the pollution produced.

Both the EU Water Framework Directive and the collaborative process that prepared it are best practice

At the European regional level, there can be no doubt that the Water Framework Directive (WFD) has proved to be the single major landmark in enabling and promoting better governance of groundwater. Its development up until its adoption in 2000 can be considered a good example of effective cooperation between policy makers, water managers and scientists, although 'governance' as a concept was probably hardly mentioned at the time. The process of implementing the WFD (Box 3.4) is also an example of successful groundwater governance and management. Among other things, implementation obliged national governments to look at whether their own institutional frameworks really encouraged IWRM and management at the river basin scale, or whether some degree of reorganization might be required.

Box 3.3

Management of groundwater abstraction in Turkey

Legal provision through Government Orders, Articles and Circulars has triggered the implementation of a large number of regulatory measures. Four critical river basins out of 25 have been closed to groundwater exploitation (no new wells or increased abstraction) by cabinet decision. Based on the Groundwater Law, wells in the four critical and 10 semi-critical basins must be equipped with flow meters and control cards to prevent abstraction exceeding allocations. Groundwater action plans have been prepared to define realistic groundwater allocations. Additional measures are being taken to transfer surface water to some drought-prone areas. The efficiency of irrigation systems is being improved to decrease water losses and measures are enforced by linking them to abstraction licenses. Capacity building projects have included awareness campaigns on TV and posters, education, information meetings for local governments and stakeholders to increase transparency, and the development of a groundwater database. Agriculture is by far the largest groundwater user in these basins and a component of the measures encourages low-consumption crops.

Chilton and Smidt, 2013; after Doğdu presentation, 2013

European regulation is successful and best practice but even there conflicts arise between production or conservation or protection goals

Since its adoption in 2000, the Water Framework Directive has dominated water management within the European Union and the Groundwater Daughter Directive has produced unprecedented efforts across the EU related to protecting and improving groundwater quality. However, even in the favorable situation created by such strong EU environmental legislation, European policy and legislation do not always move consistently in the same direction (e.g. common agricultural policy versus environmental policies; bio-fuel crops versus groundwater protection).

Box 3.4

The European Water Framework Directive

Key features and steps in WFD implementation:

- nomination of competent authorities
- establishment of river basin districts
- delineation and characterisation of water bodies
- analysis of pressures and impacts
- classification of bodies at risk
- design of monitoring programmes
- development of river basin management plans (RBMPs)
- putting in place programmes of measures.

The first two steps are the essential governance provisions which enable the subsequent management activities to be undertaken. These activities are all aimed at the achievement of good chemical and quantitative status by 2015. For groundwater quality, this requires the assessment of chemical status and the identification and reversal of significant and sustained upward trends in pollutant concentrations. The six year cycle for the development, implementation and review of RBMPs is an important strength of the WFD; the lessons learnt in the first cycle contribute to the refinement of the second cycle.

The WFD has shown itself to be robust but flexible enough to accommodate the expansion of the EU to 28 Member States with their varying physical, economic and political backgrounds. The principle of 'subsidiarity' provides sufficient flexibility to take account of these differences. Thus, quality criteria established under the WFD take account of local characteristics and allow for further improvements to be made based on monitoring data and new scientific knowledge.

Other important features of the WFD include the requirements for **stakeholder involvement** and **public consultation**, and the transparent provision of information. Development of the daughter Groundwater Directive and its adoption in 2006 have addressed weaknesses related to groundwater known to be present in the WFD.

Chilton and Smidt, 2014

Legal frameworks for transboundary aquifers

The UN Draft Law on Transboundary Rights provides a framework for transboundary aquifer management

The UN Draft Articles of the Law on Transboundary Aquifers forms a major legal milestone related to transboundary aquifers. These Draft Articles were elaborated by the United Nations Inter-national Law Commission (UNILC) and formally acknowledged by the United National General Assembly (UNGA) in 2008. Later (in 2013), UNGA commended the Draft Articles also formally to States as guidance in the framing of aquifer-specific agreements. The Draft Articles are therefore not binding and individual countries should endorse them as guidance for their conduct in transboundary aquifer management.

To date, only a few specific agreements on managing transboundary aquifers have been agreed

On the level of an individual transboundary aquifer, the countries sharing the aquifer should develop and agree on legal instruments to facilitate their effective cooperation. So far, such tools have been developed for a few aquifers in the world only: the Geneva aquifer (treaty), the North-Western Sahara Aquifer System (consultation mechanism), the Nubian Sandstone Aquifer System (agreement on monitoring and data sharing) and the Guaraní aquifer (agreement to cooperate in line with the Draft Articles). The latter two aquifer-specific legal instruments were achieved thanks to GEF projects.

Enforcement, implementation and compliance

Evidence suggest the enforcement of laws and regulations on groundwater is generally weak

Although no comprehensive studies have been carried out, the general picture that emerged from enquiries, presentations and discussions at the five regional consultation meetings is that enforcement of the laws and regulations is in most countries weak or even unsatisfactory.

In the Arab region, non-compliance is pervasive, and in all regions pollution continues largely unchecked

The general state of compliance with water regulation in the Arab world is reported to be weak (Zubari, 2013). Related to the enforcement of Arab water legislation, especially in terms of regulating groundwater abstraction and preventing the illegal drilling of wells, it is observed that a 'social culture' has spread that tolerates non-compliance and considers the cost of compliance as something that can probably be avoided. Similar flaws in enforcement of groundwater abstraction regulations, with ample possibilities to get around the rules, are also reported to be common in other regions, e.g. in Sub-Saharan Africa and in Latin America. With respect to groundwater pollution control, the situation is even much more complex, with numerous opportunities for individuals to violate the laws and regulations unobserved.

The problems are weak regulatory capacity and widespread lack of adherence to the objectives and practices of regulation — a problem that may be overcome by awareness-raising and by more community-based approaches that will engage stakeholders and promote self-regulation

Lack of compliance is no surprise in situations where the capacity of government agencies to monitor compliance is limited and numerous groundwater users and other individuals consider the regulations as a restriction of their personal rights rather than as tools that contribute to ensuring sustainability of benefits from groundwater for the society to which they belong. They key to improving compliance with the laws and regulations on groundwater thus lies in the first place in raising awareness among stakeholders and motivating them to cooperate by respecting laws and regulations. In this regard, community-based groundwater management is seen as a critical component of groundwater management and enforcement of laws and regulations.

3.6 Policy development and implementation

*Policies set **goals** — sustainability, environmental protection, equity, poverty reduction etc.; and **priorities** — allocation to urban water supply as top priority, for example*

Groundwater policies are the decisions made by stakeholders regarding what to do in the context of the governance framework. They usually define why activities are needed and when they should be undertaken or completed (Varady, 2013). Groundwater policies have to be distinguished at the one hand from laws and regulations and at the other hand from ground-water management plans. The former define legally binding principles and rules, usually replaced by new versions at a slower pace than policies. The latter are area-specific and specify the steps to be taken to achieve the policy goals set and to comply with the laws and regulations. Policies reflect preferences and therefore have a political dimension. This is very evident already in the selection of leading overall goals: sustainability of water sources (water security) or of the groundwater-related environment, adequate domestic water supply, economic development, poverty alleviation, equity, etc. Policies are modified or updated at shorter time intervals than laws, and this often happens as a result of feed-back from the field (learning processes) or changes in political color of governments. Policies and their implementation reflect the local institutional environment. For example, across South Asia, the local environment is highly unfavorable to top-down regulation — but policies involving stakeholder self-management and self-regulation have had some success (see Box 3.5).

*Policies also incorporate principles to guide planning and management, for example IWRM principles of **basin management**, **participation**, **subsidiarity**, **incentives reflecting scarcity**, and **integrated inter-sectoral management**, together with the **precautionary principle**, and the **'polluter pays' principle***

Integrated water resources management (IWRM) is a policy component that gradually is becoming embraced by almost all countries in the world. It puts groundwater in the overall water context and takes hydrologically defined areas (usually river basins or sub-basins) as elementary spatial units for water resources management. Complementary IWRM principles also apply: participation, subsidiarity, incentives reflecting scarcity, and integrated inter-sectoral management. Other important principles that are often adopted in groundwater policies are the **precautionary principle** (uncertainty should not be an excuse to postpone addressing emerging serious problems, and it should prevent decision-makers from taking premature risky decisions) and the **'polluter pays' principle** (making the individual polluter responsible for the impacts of his behavior).

*Other policy choices include: the **balance between public and private roles**; and choices on the **incentive structure** — on the right balance between infrastructure, regulation or soft economic incentives like prices and subsidies*

Another policy choice is the **respective roles of the state and the private sector**. Policies may opt for a prominent role of market forces and a minimal role of the state (e.g. in US and Chile), or rather for a strong role of the government (mostly in the countries where groundwater has been declared state ownership). Another choice to be made is on the **incentive structure** —

the desired mix of supply management and demand management measures. This will involve policies on to what extent to rely on **infrastructural measures**, on **legally enforceable regulations**, or on **'soft' measures in groundwater resources management.** The latter refer to changing the behavior of individuals (groundwater users and potential water polluters) and thus require incentives/disincentives (as practiced in India) and/or a strong focus on awareness raising and stakeholder involvement. Regarding groundwater quantity management, decision-makers have to define to be implemented.

Box 3.5

Institutional environment for Groundwater Governance in South Asia

- Large number of users with small land holdings that are overwhelmingly dependent on groundwater
- Governmental interventions favors supply-side intervention with little concern about overexploitation of aquifers
- Water quality issues not well addressed during discussions
- Laws are not enforced
- Withdrawal rights attached to land ownership, withdrawal rights not regulated, and over-abstraction becomes a phenomenon
- Introducing regulations to water use rights and subsidies are often faced with protest with political implications
- Cost for monitoring compliance is very high due to the large number of scattered water users; and even if monitoring is possible, incentives for compliance are low in the part of users
- Informal groundwater markets without any relation to regulatory authority induce further abstraction and hasten resource depletion
- Provision of energy subsidy in the form of low cost electricity could be the only connection between government and water users

Yatsuka Kataoka, Binaya Shivakoti, 2013

(After Van Steenbergen and Oliemans 2002, Mukherji and Shah 2005, Theesfeld 2008)

Box 3.6

Africa Groundwater Initiative by AMCOW

Vision: An Africa where groundwater resources are valued and utilized sustainably by empowered stakeholders.

Thrusts for action

- **Awareness:** widespread awareness of groundwater, its developmental role, its hydrological and ecosystem function, its vulnerability to human impact and approaches to its sustainable utilisation by key stakeholders at all levels.
- **Capacity:** appropriate capacity, including policy and legislation, and institutional and human resources, to plan and implement sustainable groundwater utilisation at all levels.
- **Knowledge:** a knowledge base, including monitoring networks, resource assessment, best practice database, information systems and fundamental sciences, to enable the optimal utilisation of groundwater within an integrated water resource management (IWRM) framework

AMCOW, 2008

An important factor in determining policy is the current state of affairs

The contrasting status quo in Eastern Europe and Central & Western Europe explains, for instance, why priorities for groundwater pollution control in Eastern European countries (economies in transition) are the construction of sewerage systems and water treatment plants, whereas in Central and Western European countries the key to groundwater pollution control lies rather in its link with land-use and related practices.

The quality and coverage of policies vary widely between countries, and policies may be proactive or — more commonly — reactive

While groundwater policies are comprehensive and well-balanced in some countries, they may be poor or virtually absent in other ones. There is also a difference between pro-active and reactive policies. For instance, management of groundwater in the Arab region, like the management of water resources as whole, is mostly functioning in a ‘crisis mode’. It intends to meet rapidly escalating demands and pays scant attention to water use or demand management. This type of reactive management is by no means confined to the Arab region.

Box 3.7

Payment for Ecosystem Services – Water Offset in Kumamoto, Japan

Kumamoto, located in Kyushu Island of Japan, benefits from a rich groundwater resource as a source for domestic, agricultural and industrial use. However, the groundwater level has dropped in recent years due to increased pumping and also decreased recharging capacity due to land use changes, particularly conversion of agricultural land to urban use (industry and housing) and conversion of paddy fields to 'idle-fields' in response to Japan's rice production reduction policy and the accompanying reduced rice prices.

To correct depletion of groundwater, Kumamoto City Government revised the "Groundwater Preservation Ordinance" such that it defined groundwater as a resource to be conserved as a common property of the population and introduced a variety of schemes for groundwater conservation. One example of this is the provision of a 'cooperating fee' to farmers who contribute to groundwater recharge by flooding idle fields and crop fields between cultivation periods. A private company with a factory located in the groundwater recharging area also participates in the recharge initiative under the slogan of "to fully return the groundwater we used", an initiative proposed by a local environmental NGO. This initiative was also taken up by other local companies.

Another initiative taken in Kumamoto is the water-offsetting program, which was initiated by a farmers group and Kumamoto City Government. It is designed to enhance groundwater recharging through the support of rice farming. Local companies and universities purchase 'eco-rice' — grown with less pesticides and fertilizers — from partner farms at a slightly higher in price than conventional rice. Through such purchases of eco-rice, the general population indirectly contributes to the recharging of groundwater. This resulted in an estimated water-offset contribution of 10,000 cubic meters of groundwater recharge in 2009.

Ministry of the Environment, Japan
(http://www.biodic.go.jp/biodiversity/shiraberu/policy/pes/en/water/water03.html)

Regional organizations can have a marked influence on groundwater policies of the countries in the corresponding region

The influence of the WFD in the countries of the European Union has been mentioned already. In Africa, the African Ministers' Council on Water (AMCOW) is to coordinate the strategic Africa Groundwater Initiative (see also Box 3.6). In preparation, AMCOW set out in 2007 the following important policy priorities regarding groundwater:

- Promote the institutionalisation of groundwater management by river basin organisations
- Create synergy with the parallel Rural Water Supply and Sanitation Initiative (RWSSI) to ensure groundwater's inclusion in resource assessment and the sustainable management of groundwater resources
- Secure core financial support from the African Water Facility that could be leveraged to raise additional resources from development cooperation partners, such as the European Union (Braune, 2013)

Resource management measures include technical interventions, generally readily accepted by local people, and non-technical measures to change stakeholder behavior — these measures often encounter resistance

There is a wide range of potential groundwater resources management interventions that can be provided for in groundwater policies. A distinction can be made between predominantly technical interventions that create physical infrastructure and non-technical interventions that are intended to influence human behavior. The **technical interventions** include water supply projects, artificial recharge works and other forms of conjunctive management of groundwater and surface water, water treatment provisions, sanitary landfills, sea water intrusion barriers, etc. These works are generally easily accepted by the local population, but they often require considerable investment. The **non-technical interventions** include permit systems for abstractions and other demand management measures, prohibition of handling certain chemical substances in certain areas and/or during certain periods, instructions on the type of land use permitted, obligations to treat waste water, etc. These restrictions on activity often meet opposition or are even disregarded or circumvented. Sometimes, however, creative approaches are devised (see Box 3.7).

3.7 Information, knowledge and science

Information, knowledge and science are critically important for management of the 'unseen' groundwater resource, far more so than for management of surface water

Area-specific information and knowledge related to groundwater are essential components of groundwater governance, without which it is impossible to identify the issues to be addressed and to define appropriate targets and measures in groundwater resources management. Science is needed to give adequate guidance to the acquisition and interpretation of data and information, and to transform information into knowledge. While this is true for all water resources, it needs to be emphasized that the invisibility of groundwater and its complex subsurface geological setting lead to exceptional requirements in this regard. Without science and scientific observation even a reliable conceptual model of the local groundwater system cannot be defined (unlike what is applicable to surface water systems).

The required information and knowledge cover all physical and socio-economic aspects through 'snapshots' at fixed times and through monitoring to produce time series of variables

The information and knowledge required cover a wide range of subjects: the groundwater systems concerned (aquifers); their time-dependent state in terms of groundwater quality and quality (including cyclic variations and trends); their interactions with surface water, ecosystems and the environment; groundwater abstraction and use for different purposes; social and economic benefits from groundwater; current or anticipated stresses and problems, together with their root causes; the socio-economic and political context, etc. Important activities to collect the relevant data and information are field assessment studies (producing 'snapshots' at a fixed moment in time) and monitoring (producing time series of variables). Both categories require very considerable inputs of manpower and funds.

Shallow aquifer systems are everywhere fully inventoried, but full mapping and assessment of larger, deeper aquifer systems have generally only been carried out in more developed countries

Through assessment of groundwater systems around the world, an impressive amount of information and knowledge has been accumulated, especially since the middle of the twentieth century. Numerous hydrogeological maps are available at different scales for a large number of countries (or parts of countries), for continents and even for the entire world. Supplemented by other information, these assessments make it likely that within the shallow domain — certainly within a hundred metres below ground level — hardly any significant aquifer system in the world will have remained undetected. However, at deeper levels, a different picture emerges. Only a few of these aquifers have been assessed in detail; for the majority of aquifers in the world only fragmented and incomplete information is available. Variations from country to country and from region to region are large. Comprehensive groundwater exploration, mapping and assessment programmes, carried out over decades in significant parts of the UNECE region (in particular in the United States, Russia, several West and Central European countries), have resulted in a relatively good level of information. This contrasts with the situation in Latin America and the Caribbean (where a lack of basic data prevails), Africa (highly dependent on international cooperation partners) and most of Asia (with some exceptions, such as China where regional hydrogeological surveys have started recently).

In only a few countries has groundwater monitoring been sustained over many years, and hence information and knowledge of the resource and its dynamics are usually limited

Groundwater monitoring may target groundwater levels, groundwater quality, natural groundwater discharge (springs, base flows), groundwater abstraction (wells and galleries) and seawater intrusion. Groundwater monitoring efforts have been — and still remain — very limited worldwide. Even when monitoring networks are established, they are often abandoned after a few years, e.g. due to lack of financial resources and monitoring staff after the expiration of a project. As a result, information and knowledge on the state of the groundwater resources is limited and fragmented. Nevertheless, there are exceptions, in particular countries where national or regional groundwater monitoring networks exist in combination with local monitoring networks (see Table 3.3).

Table 3.3

Selected countries where national or regional groundwater monitoring networks exist in combination with local monitoring networks

Continent	Countries
Africa	Botswana, Egypt, Mauritania, Seychelles, Tunisia
Asia	China, India, Japan, Korea, Malaysia
Australia	New Zealand
Europe	Austria, Belgium, Bulgaria, Denmark, Finland, Germany, Hungary, Italy, Moldova, Netherlands, Poland, Romania, Slovenia, Switzerland
N-America	USA, Mexico
Latin America & the Caribbean	Barbados, Brazil, Chile

(after Jousma and Roelofsen, 2004)

Box 3.8

Typical information messages to decision makers and stakeholders in the Arab Region

a) On Groundwater Management and Governance

- Groundwater resources are vital for the Arab countries and represent the only natural water sources in many countries.
- Groundwater is a scarce and vulnerable strategic resource that must be monitored, well managed and planned, conserved, and protected to ensure its sustainability
- Groundwater resources are being overexploited and are dealt with as an undervalued commodity.
- Efficient management of groundwater resources must be a priority concern to decision makers; "political will" is needed.
- Groundwater resources management reforms are urgently needed before the destruction of this essential resource.
- Appropriate legislation and polices are required to protect groundwater and control exploitation.
- Strengthening the capacity of professionals working in the water sector is needed.
- Effective cooperation is needed at all levels and between different stakeholders, especially between groundwater competing sectors, to preserve this vital resource for future generations.

b) On Groundwater Policies under Climate Change Impacts in the Arab Region

- There will be less water in the future and it will be more expensive to provide water for the ever-increasing demand.
- Although groundwater is expected to be less vulnerable to the impacts of climate change than surface water, both will be significantly impacted.
- Climate change impacts on groundwater can be direct (less recharge to shallow aquifers) and indirect (increasing demands on groundwater).
- Groundwater can be used as a buffer resource to climatic variability, and protecting and preserving groundwater contributes to increasing society's resilience to climate change.
- Adaptation options for the Arab countries on both the supply side (investing in desalination, wastewater reuse, and water harvesting especially groundwater recharge dams) and demand side (increasing water use and delivery efficiency and conservation especially in the irrigation sector) need to be evaluated and prioritized based on their cost-effectiveness

Al-Zubari, 2013

Helped by information technology and global and regional projects, sharing of information and knowledge within and amongst countries has become more effective in recent years

If area-specific information and knowledge do exist, then it is important that they are made accessible to those who need to use it for decisions on groundwater development and management. Not so many years ago, it was still very common that data collecting organizations were rather reluctant to share their data with outsiders, sometimes because of rivalry between organizations but often simply to avoid the efforts involved in data sharing. Such conditions persist in some countries or regions. For instance, in most Arab countries research centres still have difficulties in getting access to groundwater data or databases of government agencies, with the result that their scientific contribution to groundwater management and planning remains very limited. Fortunately, many organizations and countries have changed their attitude related to sharing data and information, which has been catalyzed by rapid development of information technology and also by several global or regional projects, including the transboundary aquifer projects initiated by ISARM, UNECE, GEF, UNESCWA and other entities. Nowadays numerous organizations and projects make their groundwater related data and information publicly available on the internet. Examples are the portals of the USGS and of many other national geological surveys, the Water information System for Europe (WISE), FAO's Aquastat and IGRAC's GGIS. Important for Africa is also the electronic database of scientific reports that came out of the activities of the British Geological Survey in Africa and that still represents some of the most accessible groundwater literature on the continent.

Information also needs to be made available in an accessible form in order to raise awareness and facilitate participation

Information is also needed for actors other than hydrogeologists and other scientists. Involvement of multiple stakeholders requires that each of them is informed in a way adapted to their comprehension and needs (Box 3.8 may serve as an example), in order to raise awareness and enable actors to contribute to the development of ideas and plans. Public awareness is seen as indispensable for effective and good groundwater governance, and paves the road for meaningful participation and tangible action.

Stakeholder awareness programmes are at different stages of advancement in a number of countries

Stakeholder awareness programmes are not yet carried out at the scale this would deserve. Nevertheless, several Arab countries, such as Morocco, Qatar, Tunisia, Egypt, Oman, Bahrain and Jordan, have launched several innovative public awareness, training and education programs on conserving water resources, including groundwater resources particularly in the agricultural sector.

3.8 Groundwater governance under special conditions

Several special conditions exist where groundwater governance becomes more challenging and may require specifically adapted measures:

Non-renewable or weakly renewable groundwater

Exploitation of non-renewable groundwater can be either planned mining or unplanned — but in both cases preparation needs to be made for what happens when the resource is exhausted

Non-renewable (fossil) and weakly recoverable groundwater resources are often found in areas without significant alternative water resources, hence significant abstraction intensities lead to steady depletion of the groundwater resources. Many aquifers of this type are present in the Sahara Desert and on the Arabian Peninsula. In general, there are two different ways in which non-renewable groundwater resources are being utilized. The first is **exploitation under 'planned schemes'** in which the 'mining' of groundwater storage in the aquifer is contemplated from the outset (e.g., the Libyan Sarir Basin, and Al-Sharqiyah Sand and Al-Massarat Basin in Oman). The second is **unplanned exploitation**, leading to rapid depletion of aquifer reserves and deterioration of groundwater quality. Unfortunately, this is the case in most of the Arab countries (e.g., Saq aquifer, Disi aquifer, Tawilah aquifer in Yemen's Sana'a basin and the Palaeogene aquifer on the Arabian Peninsula). Good governance requires that a long-term vision is developed in which an 'exit strategy' is prepared for the period after the resource is exhausted.

Offshore fresh groundwater reserves

Offshore groundwater is very difficult to exploit, but it could serve as a strategic reserve for the very long term

The specificity of offshore fresh groundwater reserves is they are overlain by saline seawater and hence accessing and exploiting them is much more difficult than on land. Most of the offshore fresh groundwater reserves are thought to have been accumulated during the Last Glacial Maximum, when sea levels were much lower than nowadays, thus permitting recharge of groundwater into sediments that currently form the sea bottom under the continental shelves. The global volume of these predominantly non-renewable offshore fresh groundwater resources is provisionally estimated at 3×10^5 km^3, equivalent to 3-4% of the estimated global volume of fresh groundwater stored on the continents. Whether offshore fresh groundwater could play a significant role as a source of fresh water supply in the future is not yet clear; eventually they may prove to be a resource of strategic importance when conventional water management scenarios in coastal areas are no longer adequate or sustainable (Post et al., 2013).

Transboundary aquifers

Transboundary aquifers can only be managed coherently through international cooperation

This very widespread category of aquifers has been discussed above. The challenge here is that managing the aquifer coherently is beyond the mandate of any single set of actors. Action is needed to build mutual trust and to forge cooperation between the actors of the countries involved.

Groundwater in territories under occupation

Responsible cooperation on management of groundwater in occupied territories is impeded where there is power asymmetry

An example is the Mountain Aquifer underlying the Occupied Palestinian Territories (West Bank and Gaza). The main problem is power asymmetry, which produces inequitable management approaches and prevents the occupied population from enjoying equitable benefits from groundwater — or from taking responsibility for their future as stakeholders.

Groundwater in emergency situations due to natural disasters

Where there is high risk of natural disasters, preparations to secure groundwater sources for use in emergency can be made

Emergency events (earthquakes, flooding, tsunamis, droughts, etc.) are to a large extent unpredictable; nevertheless, vulnerability to such events can be assessed. In high-risk zones groundwater governance should not be reactive, but pro-active, by being prepared. E.g. several Japanese cities have registered potential emergency wells, to be used if the municipal water supply were to be damaged by a tsunami.

Small flat islands threatened by sea-level rise

Groundwater on many small flat islands is threatened by sea-level rise — the vulnerability needs to be assessed and mitigation measures prepared

Many small flat islands, in particular in the Pacific Ocean, are not only exposed to the risk of hurricanes, storm surges, droughts and other natural disasters mentioned above but are also extremely vulnerable to sea level rise. Their main permanent water resources often consist of thin fresh groundwater lenses. Sea level rise will cause these fresh groundwater lenses to shrink, which will result in increasing water scarcity. In the light of predicted sea level rises during the present century, possible repercussions for human life on these islands need to be assessed and preparations made for adequate measures depending on the findings.

4. Groundwater governance – the missing elements

"The status and level of funding for the governance of a country's groundwater resources is usually a reflection of the perceived importance of groundwater at the national level"

(Braune & Adams, 2013)

4.1 Lack of awareness and sense of urgency

So rapid and massive has been groundwater development that both professionals and ordinary stakeholders have been too often unaware of either the potential or the risks

Groundwater is a subject often hard to grasp, even for water professionals, let alone those who operate a well or who depend on groundwater for their domestic water needs, livelihoods or otherwise. Often, local populations have until recently not been aware of considerable groundwater resources beneath their feet and the advantages these resources might offer in comparison with alternative local sources of water. As a result, opportunities to enjoy benefits from groundwater have not been taken advantage of fully in many areas. Furthermore, major problems related to groundwater — like **progressive depletion** in arid regions and **widespread pollution** in all parts of the world — have taken communities and nations by surprise, and similarly for **impacts on ecosystems and the environment**.

Only in recent years, as awareness of groundwater problems and opportunities increased and more knowledge has become available, have groundwater organizations and other stakeholders begun to turn from 'reactive' mode to a more forward-looking and proactive approach to groundwater

Only as problems have emerged — and with this vast, hidden resource the problems are often slow to be detected — have most people become aware of the need to understand groundwater better. Now, supported by scientific analysis, people have started learning about groundwater and its interdependencies, processes and patterns. This is widening their awareness of opportunities and problems related to groundwater. As a result, organizations in charge of groundwater and other stakeholders have started to change their attitudes from a reactive to a proactive mode.

However, awareness remains low in many countries and all too often groundwater management remains in 'crisis' mode

Awareness on groundwater and its many facets is still very limited around the world. This is seen as a fundamental obstacle to the development of effective groundwater governance. In many countries, groundwater is generally seen — not only by groundwater users but also by governments — as a commodity to be pumped and used, not as a resource that also should be carefully managed and protected. This perception results in the absence of a sense of urgency for groundwater resources management; consequently, the subject is not on the political agenda and does not develop. Emerging problems (that could have been anticipated and perhaps avoided) are addressed in a 'crisis' mode, often without being satisfactorily solved, partly because local stakeholders do not understand the problems and are reluctant to cooperate with the government agencies.

Countries with longer traditions of groundwater management and with political vision and well-resourced agencies are better placed to manage the resource, but even there, stakeholder participation often remains inadequate — and new issues like competition over land use of sub-surface activities are emerging

Much better conditions are observed in countries where groundwater institutions are in a more advanced stage, usually countries with a long tradition in groundwater investigations and with sufficient financial means for the public sector. In such countries, the mandated government agencies often have well developed perceptions and a clear vision related to groundwater, which enables them to propose and initiate significant groundwater resources management programmes. But even under such favorable conditions, awareness still has its limits.

In several of these advanced countries the link of groundwater management with a range of subsurface activities and with land use is insufficiently taken into account, while awareness amongst multiple stakeholders has not yet reached a level that is required for their active participation in groundwater governance. For the awareness raising among different categories of stakeholders a variety of dedicated methods and materials will have to be prepared and used.

4.2 Shortcomings regarding data and information

Time-independent data

With some exceptions, the information needed for aquifer management is generally lacking

As mentioned above (Chapter 3), hydrogeological maps that give an impression of the local groundwater systems are available for most countries, although of variable quality, but beyond this level there are still significant gaps. Only for a limited number of countries (in particular in the UNECE region) is there sufficient area-specific information and knowledge on groundwater systems present to allow general studies and analysis on groundwater to be carried out without first making major investments in field assessment studies. Admirable initiatives have in some regions produced easy access to hydrogeological information of good quality; a recent example is the transboundary aquifers inventory by ESCWA for West Asia. Nevertheless, in the majority of the countries, especially in Africa and in Latin America and the Caribbean, hydrogeological information is only fragmentary present or hardly available. Estimating the groundwater potential of individual aquifers and identifying the issues to be addressed by groundwater management is thus difficult.

Often relevant data is held by mining or oil and gas companies but this is usually not shared

The private sector — in particular the mining sector and the oil and gas industry — owns large quantities of data of high public interest from the point of view of groundwater exploration and assessment at greater depths. Nevertheless, so far these data are seldom shared.

Time-dependent data

The monitoring of the time-dependent essential to management is weak in most countries and, despite the advent of efficient, low cost new technology, monitoring is even deteriorating in some locations

The current situation regarding time-dependent variables is generally even worse. Groundwater levels, groundwater quality, groundwater abstraction, natural groundwater discharge and sea water intrusion are consistently monitored in only relatively few areas in the world. Even countries with operational regional or national groundwater monitoring networks mostly focus on a limited number of monitoring variables, e.g. groundwater levels and selected groundwater quality parameters only, or only on groundwater abstraction. Since time-dependent variables are indispensable for the diagnostic phase in groundwater management and for assessing the impacts of groundwater management measures, the lack of monitoring data is in most countries a major obstacle to effective groundwater management. This situation is confirmed by, for example, the statements made at the Third International Forum on Water Governance in the MENA Region (Marrakech, 2008) and with the concerns of the AMCW at its Pan-African Conference in 2003. Few countries reach the high standards required by the Groundwater Daughter Directive of the WFD in the European Union which sets the benchmark for professional monitoring requirements. By contrast, there even appears to be a world-wide tendency towards reducing monitoring efforts rather than intensifying them. Even though new technology such as sensor technology and wireless data transmission should be making monitoring easier and cheaper, their introduction appears to be constrained by declining support for traditional (in-situ) data acquisition programmes.

Sharing data, information and knowledge

Although some countries have made great strides in making information accessible to technicians, decision makers and the general public, too often information is not available or it is scattered or not presented in a way accessible other than to specialists

Sharing data, information and knowledge is essential for effective groundwater governance. It enables decision-makers to make properly informed decisions; scientists and planners to guide the decision-makers by sound analysis and effective plans; operational water managers to act according to policy and plan; and local stakeholders (groundwater users, water suppliers, the general public, etc.) to understand what is at stake and to articulate their interests, views and preferences properly.

A number of countries have made considerable efforts to make their groundwater data, information and knowledge publicly accessible, in particular via internet portals. However, in most countries, organized databases either do not exist or are not yet publicly accessible. Too often data is still scattered over many organizations, instead of being concentrated in one central repository (e.g. a geological survey). This applies not only to processed data, but also to reports and maps. Too often even accessible databases and other publicly accessible sources of information on groundwater are in a format suitable for professionals engaged in scientific research, or support in policy development and management planning. Information systems or other information products (books, brochures, DVDs, etc.) tailored to the needs of local stakeholders and the general public are still extremely rare.

4.3 Legal 'blind spots'

Scope and comprehensiveness of domestic legislation

Although all countries have some legislation on groundwater, it is frequently scattered across several instruments and may be partial, inconsistent or out-dated

Virtually all countries have legislation addressing groundwater in one way or another, albeit sometimes only as a minor aspect in general water law. Provisions, however, are often fragmented, with groundwater aspects scattered over a large number of articles or laws that are not always mutually consistent. Fragmentation is especially observed in regions where the legislation is old (especially reported for African countries) and this old legislation may be out of line with current national and international best practice. In some countries, either institutional responsibility for groundwater governance is not clearly assigned or there are many institutions and legal instruments involved.[8]

Legislation on groundwater quantity ad on quality is usually separate, which can be an obstacle to management

Even in regions where fragmented legislation gradually has been replaced by more comprehensive groundwater law, there is often still a marked separation between groundwater quantity and groundwater quality legislation. In the United States and India, for instance, there is no single federal law governing groundwater resources: groundwater quality is regarded as

[8] This was noted for the UNECE region but it probably holds true also for countries in other regions.

a federal issue, while groundwater quantity is a state issue. A similar situation, can also be found in European countries.

Customary rights are often ignored in legislation, which is likely to lead to problems in application — and even to negative impacts on marginalized people

Customary rights to land and water in rural Africa appear not to have been considered in the drafting and implementation of water legislation in the region so far. This may be a serious omission, because new laws could be rejected in large parts of the country and even across national borders in the case of pastoralists. It could also lead to disenfranchisement of the weakest in society, particularly serious as agri-business expands in rural Africa. Alternative as well as supplementary approaches might have to be considered (Mechlem, 2012). There are also indications that modern water legislation in countries of the Arab region is not completely compatible with customary rights.

Existing legislation typically does not favour inter-sectoral coordination

Laws regulating land use, the construction sector, mining and other subsurface activities mostly seem to have been drafted without any attention paid to the interaction with groundwater.

Legislation often appears 'theoretical' — poorly adapted to the realities on the ground and hard to implement

Given the reported inadequate compliance and poor enforcement of the enacted legislation in many countries (e.g. in the Arab region and in Sub-Saharan Africa, but also elsewhere), laws may not always have been drafted with sufficient consideration for the local realities in the field and the limited capacity of the competent government agencies.

Groundwater ownership and user rights

To counter private over-exploitation of groundwater, many countries have reserved legal ownership of groundwater to the state

The open access and common pool characteristics of most groundwater systems tend to trigger excessive rates of groundwater exploitation in water-scarce areas, in particular in arid and semi-arid zones. Properly defined private ownership and user rights in groundwater are no guarantee against the harmful depletion of groundwater storage under such conditions.

This is why an increasing number of countries have allocated groundwater ownership and user rights to the public domain of the State in their most recent groundwater legislation.

Under conditions of scarcity and low recharge, situations where there are private groundwater rights or where the local people assume that they — not the state — own the groundwater are unlikely to be conducive to orderly and sustainable management

How to define groundwater ownership and user rights is up to the respective countries, but a few comments can be made. The first one is that in areas of intense groundwater pumping and low to moderate groundwater recharge (example: the Ogallala aquifer in the US) it may be more difficult to achieve and maintain a state of sustainable groundwater exploitation under private groundwater ownership or user rights than under state ownership. Secondly, in many cases there may be a large discrepancy between the legal status of groundwater and the perceptions of the local population on this subject. Where that is the case, this may lead to practices that massively ignore or reject the adopted legal principle, as is the case in many Arab countries.

Legal tools for transboundary aquifers

The evolving UN instruments on transboundary aquifers can serve only as guidance…

The UN Draft Articles of the Law on Transboundary Aquifers form an extremely important tool in support of transboundary aquifer management, but since they are not binding they only will have significant impact if they are endorsed by individual countries and used as guidance in negotiating treaties and agreements. Although the Draft Articles were acknowledged by the UNGA in 2008 and formally commended to governments as guidance (UNGA, 2013), there is still discussion on the eventual format of the relevant instrument, and on its relationship with the 1997 UN watercourses Convention.

… and this guidance has so far been translated into only a few agreements of relatively limited application

At the level of individual transboundary aquifers, treaties or other legal arrangements should support and guide cooperation between by the countries involved and their and joint management of the aquifer's groundwater resources. So far, such legal tools are available and have been agreed upon for only a few of the hundreds of transboundary aquifers in the world. And even among these few, most of the legal tools are either very generic (Guaraní agreement) or addressing only some aspects of transboundary aquifer cooperation (North Western Sahara Aquifer System, Nubian Aquifer System).

4.4 Areas of policy neglect

In general, groundwater tends to be a 'poor relation' in water policy

Typically groundwater policy has been less well developed than other natural resource policies. This is because of the newness of large scale groundwater development, of the limited awareness of the issues, of the largely decentralized way the resource has been developed, and of the sheer difficulty of addressing issues. As a result, many countries have poorly developed policy frameworks for groundwater. In fact, in some countries there are no specific policies on groundwater at all.

Limitations in legislation are reflected in the policies countries have adopted, particularly neglect of linkages among sectors

Several of the deficiencies in domestic legislation, as outlined above, are mirrored in policies. These include an often limited scope of the adopted policies, focusing on one single sector or on groundwater in isolation from other components of the water cycle, and neglecting the existing and obvious linkages between water, energy and food and the additional emerging links to ecosystems, climate change, land and subsurface use, globalization of the economy and political power shifts. Inconsistencies between policies of interlinked sectors (water, agriculture, energy, health, environment, etc.) are not uncommon and often there is a lack of provisions that ensure sufficient coordination between these sectors.[9]

9 An example is the recent (2013) plan of the Minister of Economic Affairs of The Netherlands to initiate test drilling for shale gas exploitation in a pilot area. He had been advised by a consortium of two consulting companies, but neither the national Geological Survey, nor the local water supply company (dependent on groundwater), nor the local population had been consulted to underpin decision-making. Ignorance or political opportunism? Anyhow, protests of the bypassed stakeholders resulted in abandoning the plan.

In Africa, generally, the potential of the vast groundwater resources to support growth and to reduce poverty is not yet widely reflected in policy

For the African region, the vitally important social, economic and environmental role of groundwater in achievement of development goals is still largely unrecognized and undervalued. The choice of the domestic water supply systems often remains biased towards surface water, irrespective of the characteristics of a given area and the nature of groundwater occurrence. Groundwater's vital role towards the next stage of poverty alleviation, including water for agriculture and sustainable food security, tends to be poorly understood.

At the other extreme, some developed countries have given aquifer restoration too high a priority and have wasted resources in the process

Sometimes completely unrealistic goals are pursued, resulting in frustration and massive waste of efforts and funds. An example is the huge investment in the US to restore aquifers to pristine conditions (Ronen, Sorek and Gilron, 2012).

The time horizon of politicians and decision takers is often too short — and their awareness of issues is too limited — for them to endorse the long term vision needed to manage a natural resource like groundwater

A time mismatch between the political and hydrological/environmental cycles often results in only a short-term (4 to 5 year) vision of political decision-makers — compared to the much longer time needed to establish good groundwater governance and to produce tangible impacts of groundwater management measures. In addition, poor familiarity of decision-makers with groundwater, limited communication between groundwater specialists and decision-makers, and the inclination of political decision-makers towards avoiding unpopular measures all may lead to policies that pay insufficient attention to long-term goals and benefits.

Few countries have developed the policies and management approaches for transboundary aquifer management

Although major progress is reported in several regions in relation to transboundary aquifers, practical instruments and approaches that enable and encourage transboundary groundwater management at field level are generally still missing.

4.5 Poorly adapted policies

Large scale and widespread groundwater development is a relatively new practice. Often policies have been designed rapidly in response to opportunities or problems and results have been poor — or even counter-productive. Examples of poorly-adapted policies discussed here are:

- Drilling programs undertaken by governments that failed as there was insufficient stakeholder involvement
- Programmes to reduce groundwater overdraft by increasing efficiency, but which resulted in **increased** depletion
- Subsidies that may have been effective in reducing groundwater overdraft but which increased inequity in access to groundwater
- Attempts at regulating groundwater through permits where the regulatory agency lacked capacity or where the population at large rejected the regulatory programme
- Introduction of a fee system to stem pollution where there was inadequate capacity to administer the scheme or fees were too low to deter polluters

Early government programmes to develop groundwater for communities often failed because of lack of participation — a fault now largely corrected through more stakeholder involvement in current programs

Borehole and well construction programmes for rural water supply in developing countries, carried out by government or donor agencies without any involvement of local stakeholders form a classic example. In general, the intentions were commendable and the approach — using technically qualified teams — looked at first sight adequate and efficient. Nevertheless, operation and maintenance after well completion used to be left to the local population that had not been involved in the programs and often lacked a feeling of ownership of the technical infrastructure. As a result, many of these wells and the corresponding pumps passed into disuse rather quickly. Roughly from the 1980s onwards, this flaw in approach gradually became recognized and a significant role for stakeholders was planned in many of the later well construction programmes. This approach created local ownership, made the local population from the outset responsible for operation, maintenance and cost recovery, and gave them sufficient training to perform these tasks properly. Box 4.1 summarized some lessons learned in Africa on this subject.

Box 4.1

Lessons learned: Implementation of groundwater for community water supply in Africa

"The rapid growth of community water supply from groundwater sources since 1994 presents a major learning opportunity for a new groundwater for livelihoods thrust.

"Attempts to centrally plan and implement schemes without the complete buy in of communities have met with limited or no success. A clear and mutually understandable definition of the role the community plays in the conception, installation; operation and maintenance of the water system must be spelt out and recorded. The importance of this aspect of any plan cannot be overemphasized.

"Once buy in has been obtained from the community, the process of empowering the relevant role players can begin. Empowerment (capacity building) plays a vital role in ensuring long term viability of any water system.

"Any technology applied in rural areas must be appropriate and sustainable. Communities must be part of the technology selection.

"Rising expectations ensure that the objective of providing for basic needs is something of a moving target.

"Any plan which aims to improve access to clean water will have to take into account the possibility that the increased consumption that will inevitably happen can be met by the available supply. The objective therefore is to implement a system which will reward responsible use of water while making indiscriminate consumption difficult and demanding.

"Role players such as drillers, pump installers and suppliers must be consulted. There is a wealth of information available which has been accumulated during previous projects of this nature and it would be bode well for any new project to collect this information and apply it in the most cost effective manner."

John Tonkin, President: Borehole Water Association of Southern Africa (Tonkin, 2009).

Programmes to help farmers reduce pumping by increasing irrigation efficiency have sometimes had the opposite effect, as farmers simply expanded the irrigated area — and increased conveyance efficiency contributed to lower groundwater recharge

Improving irrigation efficiencies as an overrated 'solution' to combat groundwater depletion in arid regions is a second example. Organizations that have promoted this measure in their projects often tacitly assumed an extent of irrigated lands invariable in time and thus expected less groundwater to be abstracted if irrigation efficiencies would be improved. In practice, however, the effect in terms of groundwater depletion was often opposite to the intended effect: more depletion instead of less. The reason is the behavior of farmers: they usually preferred expanding their irrigation perimeters while pumping the same volumes of groundwater, of which due higher irrigation efficiencies a smaller percentage returned to the aquifer. Of course, the increased extent of irrigated land was likely to produce higher economic benefits.

> *Where subsidies have been used to restrict groundwater development in already over-exploited areas, this has tended to freeze existing patterns of rights and to restrict access by the poor*

Financial incentives are used in some countries as an instrument to control groundwater abstraction. In the case of India, the National Agricultural Bank for Development (NABARD) provides credits to farmers for the construction of irrigation wells and related investments (pump set, pump house etc.). Whether or not credits are granted depends on the stage of groundwater development in the zone where the new well is projected, as defined by the corresponding state groundwater organization: safe, semi-critical, critical or overexploited. This contributes to controlling groundwater abstraction in the critical or overexploited zones, but can penalize those whose livelihoods depend on continued access to groundwater.

> *Permitting can be effective in groundwater regulation but in some situations this approach to regulation is ineffective — for example, where agencies lack capacity to administer the system, or where society generally rejects the regulatory approach*

In principle, permit systems for drilling wells and for pumping groundwater are a powerful tool to regulate groundwater abstraction, which has been proven in several countries. Nevertheless, there are also several countries where such systems have been introduced but turned out to be ineffective. In some cases this depends on the governmental agencies in charge. Taking a decision on a permit to be granted or refused requires clear criteria to be available and local information to apply these criteria. Some agencies do not have such criteria and information, do not make any effort to acquire these and simply grant a permit whenever it is applied for. In this way, the permit system degenerates to an administrative system of collecting permit fees. But non-functioning of permit systems may also be due to the attitude of those who have to apply. In some regions (e.g. the Arab region) it is not uncommon that people massively ignore the regulations and simply drill illegal wells, which leads to a social culture which tolerates non-compliance and considers the cost of compliance as something that can be avoided. There are also several ways to deal improperly with the permit system and the implementing agencies, including acts of corruption. The **lesson** is that regulation has to be adapted to local realities — and stakeholder attitude and buy-in is always vital.

Regulating pollution through pollution fees is only effective where the regulatory agency has capacity — and where fees are high enough to be a deterrent

Collecting fees on the basis of the 'polluter pays principle' is a potentially powerful instrument to reduce groundwater pollution. However, it requires an organization with sufficient capacity and dedication to identify polluters. Furthermore, the fines to be paid should be sufficiently high to motivate potential polluters for preventing or reducing pollution from their activities or behavior. Otherwise the 'polluter pays principle' would easily be perceived as a mechanism to obtain a 'licence to pollute'.

4.6 Limitations of organizations and other actors involved

Government organizations

Government organizations take the lead in groundwater management — but their capacity and performance is variable

Government organizations play an important role in groundwater governance: they are supposed to take the lead in governance, to coordinate with all other actors and to take care of the regular groundwater management tasks at different levels, ranging from policy development and decision-making to the implementation of measures in the field. Around the world these government organizations differ very much in capacity and size, but even more in performance.

In many developing countries — and even some rich ones — government institutions perform poorly with fuzzy mandates, scant staff and human capacity, limited political support or institutional authority, and inadequate budgets

In terms of mandates and capacity most of the wealthier countries of the world (many of them located in the UNECE region) consider their government institutions adequate to address groundwater issues and even perform well. Elsewhere, but also in rich oil producing countries of the Arab region, many deficiencies are reported: **unclear and fragmented mandates, limited**

and insufficiently trained staff, and **low scientific and technological competences**. Often the institutional set-up has not progressed much beyond the hydrogeological service function at national level, with a presence in regional offices linked to the national department. Evidently, the capacity of the government agencies depends to a large extent on **political support** and the **budgets** made available for groundwater agencies; both are often very low. Deficiencies in human resources are clearly a key factor explaining poor and ineffective governance of groundwater resources in many parts of the world.

Fragmentation and lack of clarity on responsibilities amongst agencies is a common problem

Fragmentation is ubiquitous and results often in poor coordination between the government institutions in the water sector. This includes coordination between different government levels; especially in countries with a federal government structure, the division of responsibilities between Federal and State or Provincial levels is not always clear. More generally, institutional responsibilities for groundwater governance are often not clearly assigned, while there are many institutions and legal instruments involved.

Partly for historical reasons, agencies tend to take a top-down engineering approach, whereas the challenges of the complex socio-economy of groundwater require also a complementary bottom-up stakeholder involvement approach

At operational levels, sensitivity to broader governance issues is often low, while at higher political and policy levels, understanding of practical issues is commonly weak. Historically, most government agencies in the water sector have been established for tasks in the engineering domain, like water supply, drainage and irrigation, flood control, etc. This has caused the operational style in many of the water institutions to be more ‘top down’ than ‘bottom up’. Because of the more diffuse nature of its use and the potential roles of numerous stakeholders, groundwater management and governance need more ‘bottom up’ approaches.

Stakeholders and the general public

The role of stakeholders has generally been limited and their approach has been remarkably passive

In most countries, private groundwater users and other non-government stakeholders have so far played a very limited role in groundwater governance. Their attitude in this regard is mostly passive: often they have little understanding of the benefits of groundwater management and feel restricted in their behavior by government regulations, which they either comply with or try to circumvent. In several countries this negative perception is aggravated by a lack of trust confidence in the government.

Stakeholder involvement is partly due to lack of awareness or knowledge

One of the main reasons why the active involvement of stakeholders in groundwater governance is limited is the lack of knowledge on groundwater and a lack of awareness what opportunities and problems are offered by these resources. In short, they have little notion of what is at stake and what their role might be in achieving possible improvements. While those who abstract and use groundwater are usually aware that their operations interact with groundwater, this often does not apply to the general public who are may be unaware that they are dependent on groundwater for year water supply, or who may be potential polluters.

Ideally, there should be an aquifer-level organization with representation of all stakeholders

Another problem is formed by the practicalities of the participatory processes. Stakeholder participation beyond the levels of complying with regulations and of aligning personal behavior to optimal societal benefit requires adequate organizational structures. It is not feasible nor efficient for each one of the numerous individual stakeholders to be directly involved, so representative structures need to be set up. Representation of certain groups by government agencies with a related field of interest (e.g. farmers represented by the Ministry of Agriculture) is sometimes observed but is certainly not satisfactory. Water User Associations (WUA) can be representative – but only of their own interests. There is a definite need for a system of higher-level user and stakeholder participation. This could be in the form of an aquifer management organization (AMOR) formulated at the scale of the basin level by the water regulatory agency, and in which all WUAs and other main categories of stakeholders are represented. Such aquifer centred user organizations are rare with the closest examples coming out of the Hydrological Unit Networks deployed under the APFAMGs project.

Cooperation between the different actors

Cooperation amongst stakeholders can be initiated through awareness programmes and through development of an inclusive organizational model favouring transparency and accountability — but moves towards such a model have so far been tentative and limited

Except for some projects where small-scale physical measures are implemented (e.g. community well schemes or minor artificial irrigation works), balanced and smooth cooperation between all relevant actors in groundwater governance is far from being a reality almost anywhere in the world. In many countries, even initial steps to move from a centralistic governance model dominated by the government to a more participatory governance model still have to be made. These steps include awareness programmes for all categories of actors, improving accountability and transparency of the government agencies, defining the different categories of stakeholders and who is going to represent them, and the development of tailor-made communication structures and cooperation methodologies.

There is considerable benefit — for all parties — to be gained from public/private cooperation

Cooperation between the public and private sectors has much more potential for synergy than is currently being utilized. For instance, companies involved in groundwater and/or subsurface activities (mining industry, oil and gas companies, beverage and food industry, etc.) could make significant contributions to groundwater management by sharing the subsurface information they possess and by aligning their activities better with the adopted groundwater management goals. As was illustrated during a public-private sector panel discussion at one of the regional consultation meetings of the Groundwater Governance project, there are prospects for enhancing such public-private partnerships, to be catalyzed by awareness raising, identification of incentives and potential benefits for all parties involved and development of effective communication and cooperation mechanisms (Van der Gun, no date).

4.7 Financing of groundwater governance initiatives

Levels of financing for groundwater agencies are generally low, and sometimes so low as to impair activities critical to sustainable management

Shortage of financing is a constraint to groundwater governance in almost all countries of the world. Financing levels vary considerably, generally correlated to the overall financial situation of the countries. In some countries financing is so limited that groundwater agencies cannot deliver even a minimum of the critical activities required, which threatens the sustainability of water supply and environmental services provided by the groundwater resources.

Agencies need to work to raise groundwater issues higher up the political agenda in order to secure commitment and financing

Government agencies in charge of groundwater management tasks usually receive their core financing from government, but frequently they seek additional financing. One straightforward approach is simply to make efforts to boost the political will of the government and convince it of the need to increase its financial commitment to groundwater. In other words: groundwater should be lifted to higher on the political agenda. This will require the groundwater staff not only to present solid argumentation but also to become familiar with the way politicians think (which is rarely a competence of hydrogeologists).

There is also usually scope to increase revenues from fees and fees — but this should not be to the detriment of the agency's main mission

A second approach is generating income from groundwater users and groundwater polluters (permit fees, use and pollution taxes and fine, etc.) as a recovery of the groundwater management costs. There seems to be scope for implementing such cost recovery approaches far beyond its current application. However, this can be to the detriment of their proper tasks — for example, issuing more licences than they should in order to boost their budget.

Agencies may also provide services to third parties, although this is unlikely to be a main income stream

A third observed approach is earning income by providing services to third parties. Often this includes well drilling, sometimes also field surveys (e.g. geophysics) or specific groundwater studies. This may be a useful approach to prevent an agency to be discontinued during a critical period, but the additional income mostly will only recover the cost related to the services, thus will be of no or little use for funding groundwater management tasks.

Involving donors can boost financing in the shorter term — and can also help persuade governments of the need for governance improvements — but in the long run, agencies will have to fall back on national financing

A fourth approach is complementing the budget by donor funds. In some regions, notably in Africa, has this created an almost complete dependency on donor funding, which may be convenient in the short term, but is a risk for the future. Considerable efforts will still be needed in many countries before they can rely on their own funds in the mid- and longer term. Besides increasing the budgets and achieving project goals, donor investments may also favorably influence the mindset of governments and become an external factor that can drive reform processes. In the Arab region, for instance, the political will for reforms towards more effective water governance has been observed to be proportional to the involvement of international donors and funding agencies in water sector projects (e.g., Yemen, Egypt and Morocco).

4.8 Summary — the missing governance elements

Gaps, flaws and lags in governance are pervasive but they vary according to the local setting and stage of groundwater development

The gaps, flaws and lags in groundwater governance identified in the five regional diagnostic reports are summarized in Table 4.1, under each of the four main governance components. Most of these include a degree of subjectivity, since qualifications like ‘lack of’, ‘poor’ or ‘insufficient’ result from comparing the present situation with certain assumed minimum requirements that in most cases are difficult or impossible to specify. The types of gaps and flaws that really matter vary considerably from case to case, depending on the local setting and the stage of groundwater development and management (as defined in the previous chapter: pre-management, initial management and advanced management stages). For instance, in urban and industrial or intensive agricultural areas the most critical gap in groundwater governance may often relate to effective pollution control, but in areas where water-resource shortage predominates, ensuring that provisions for effective demand management and resource augmentation are in place is likely to be most critical.

A short-list of the missing elements would be different for each country or area, but there are several critical gaps common to many countries, notably those countries in the pre-management or initial management stage:

- **Lack of effective leadership in groundwater management,** with the result that few measures are implemented, or implemented measures are ineffective and fail to produce the desired outcomes. Common causes are poor mandates, limited groundwater expertise, understaffing and insufficient budgets of the government agencies in charge. This situation is in many cases aggravated by lack of political support, weak stakeholder involvement and underestimation of the difficulties encountered in the daily practice of groundwater management.
- **Insufficient awareness at all levels** about the opportunities, interdependencies and threats regarding groundwater, both in the short and the longer term. This is partly caused by lack of information, partly by insufficient dissemination of available information in a form accessible by different target groups. This lack of awareness results in little or no groundwater management action (because no sense of urgency is felt), or — if action is taken or planned — in poorly defined management goals, short-sighted plans with limited scope, lack of consensus among actors on priority actions, ineffective measures and little or no active involvement of relevant stakeholder groups.
- **Limited ability of potential actors to cooperate effectively and successfully for achieving the common groundwater management goals.** In practice, it appears difficult to develop good relationships and effective mechanisms for cooperation — not only between the public sector and local stakeholders, but also between the public and private sectors, and even between different public sector agencies. Preconditions for success are trust-building and adequate communication between the parties concerned, accountability and transparency of the government agencies, and positive motivation for groundwater management (triggered by raised awareness) among all potential actors.

Table 4.1

Overview of the main deficiencies in groundwater governance

Component	Common or occasional deficiencies
Actors	• Lack of awareness/understanding of groundwater and its role, problems and opportunities (potentially applicable to all categories of stakeholders) • No sense of urgency for governing groundwater properly • Low political commitment related to groundwater issues • Reactive rather than proactive attitudes • Poorly defined mandates or responsibilities of government agencies • Insufficient capacity of government agencies • Poor budgets of government agencies, or dependency on foreign parties • Lack of initiative and commitment of mandated government organizations • Poor accountability and transparency of mandated government organizations • Lack of cooperation between involved government agencies (or even rivalries) • Poor law enforcement or implementation of certain instruments (e.g. licensing) • Poor stakeholder involvement in groundwater governance • Lack of trust between the different categories of actors • Lack of adequate communication between all relevant partners • No balanced and smooth cooperation between all relevant partners
Legal frameworks	• Fragmentation and inconsistencies in legislation • Old groundwater legislation out of line with current views • Groundwater quantity and quality in separate laws • Groundwater law separate from laws governing surface water, land use, mining, subsurface use, environment, etc. • Institutional mandates and responsibilities not clearly defined • Overlapping institutional mandates and responsibilities • Laws ignoring customary rights • Laws inconsistent with realities on the ground (e.g. institutional capacity or perceptions of local groundwater users) • Draft Articles on the Law on Transboundary Aquifers not yet endorsed by countries • Legal instruments existing for very few TBAs only

Table 4.1

(Continued)

Component	Common or occasional deficiencies
Policies and management planning	• Limited scope (single use sector and/or neglecting obvious linkages) • Inconsistencies with policies of related domains • Potentially vital role of groundwater overlooked or undervalued • Waste of money due to pursuing unrealistic goals • Short-sightedness (due to time mismatch between political and hydrological/environmental cycles, or ignorance) • Overlooking the importance of involving stakeholders • Lack of practical instruments and approaches for transboundary aquifer management • Wrong 'solutions' due to insufficient knowledge of human behavior • Negative impacts of some categories of incentives • Inadequate design of certain types of instruments (e.g. licensing systems, pollution fines) • Lack of regular systematic planning for groundwater management and protection
Data, information and knowledge	• Lack of sufficiently detailed groundwater assessments (especially in Africa and in Latin America & the Caribbean) • Monitoring of time-dependent variables is rare and often only fragmentary • Sharing data and information is still in its infancy • Presentation of information not tailor-made for the different categories of actors

5. Addressing the gaps in groundwater governance

"Care for groundwater today means healthy citizens and ecosystems tomorrow"

(Balaet, 2013)

5.1 Success stories and other positive experiences as guidance and for inspiration

Success stories can provide valuable lessons, although whether lessons can be applied elsewhere requires careful study

Success stories and identified best practices (Table 5.1) are a valuable source of inspiration for addressing groundwater governance gaps and flaws. Nevertheless, a critical approach is necessary to verify whether reported successes are sustainable, and to assess whether and under which conditions they are replicable.

In spite of the many governance deficiencies listed in Chapter 4, numerous instances of significant progress in groundwater management — and even success stories — are being observed worldwide, which bear witness to the existence of effective governance provisions.

Table 5.1

Selected success stories and other examples of progress in groundwater governance and management

Category	Selected examples
1. Governance	
A. Actors	
Public sector reform and strengthening	In many countries: reduction of institutional fragmentation; separation of resource management from resource user agencies; better definition of mandates and tasks; capacity building.
Stakeholder participation	Technical Groundwater Committee COTAS (Mexico); Water boards (The Netherlands); Llobregat aquifer (Spain); Falaj communities (Oman); El Bsissi Aquifer (Tunisia); Ghash River groundwater basin board (Sudan); Contract management of aquifers (Morocco); High Land Water Forum in Jordan; Wafra Farmers Stakeholders Committee, Kuwait; Karst water management body, Namibia; Farmer-managed irrigation at Samgar, Tajikistan.
Catalyzing international, regional or federal initiatives	Millennium Development Goals; WFD and its Groundwater Directive (EU); Superfund (USA); AMCOW (Africa); SADC (Africa).
B. Legal framework	
Domestic law and regulatory Frameworks	Legal reforms in many countries; Updating groundwater-related legislation in accordance with modern views on groundwater and its functions.
Transboundary aquifers	Draft Articles of the Law on Transboundary Aquifers (UNILC/UNESCO); UNECE International Water Convention on Transboundary Watercourses and Lake ('Helsinki Convention'); Guaraní Aquifer System agreement (Argentina, Brazil, Paraguay, Uruguay); Joint management of the Geneva aquifer (France, Switzerland); Cooperation on the North Western Sahara Aquifer System (Algeria, Libya and Tunisia).
C. Policies and planning	
Policies and management planning	Widespread adoption of the IWRM approach and the sustainability principle; Adaptive management approaches; 'Laboratory in Nature Project' in Argentina.
D. Information & knowledge	
Science, data acquisition, and sharing data and information	New technologies related to data and information (sensors, telemetry, GRACE, ICT, etc.); Role of international organizations and programmes (UNESCO, FAO, GEF, World Bank, ESCWA, ISARM, etc.), networks and associations (Cap-Net, Awarenet, IAH), UNESCO Chairs, international centres and initiatives for information and data dissemination (Aquastat, WISE, GW-MATE, IGRAC).

Table 5.1

(Continued)

Category	Selected examples
2. Management	
Groundwater quantity management	Functioning permit systems for wells and groundwater abstraction; Litigation as a control to excessive abstraction (USA); Managed aquifer recharge (MAR); Energy pricing (India); Payment for ecosystems services (Japan); Disaster preparedness (Japan).
Quality management and pollution control	Reducing backlog of sewerage infrastructure and wastewater treatment in several countries (e.g. in the Arab region)'Polluter pays' principle widely adopted Groundwater Daughter Directive of the Water Framework Directive (European Union)

(as mentioned in the five Regional Diagnostic Reports on Groundwater Governance)

Table 5.1 shows examples selected from the five regional diagnostic reports on groundwater governance.[10] Collectively these selected examples cover the main facets of groundwater governance (actors, legislative frameworks, policies and plans, information and knowledge) and groundwater management (groundwater quantity management, pollution control), but individually most deal with only some of the facets.

The local context and stage of groundwater development and management need to be considered in adapting lessons, and actions should be prioritized to the main targets or problems and should be feasible and affordable in the local context

When considering how to replicate progress made elsewhere, one should take into full account the local context of the groundwater system under consideration, in terms of its hydrogeologic, socio-economic and politico-institutional conditions. Very important in this context is the stage of groundwater resource development and management described earlier (Section 3.2): pre-management stage, initial management stage and advanced management stage. Proper consideration of the local context will help to focus attention on the currently most critical deficiencies, and selecting options for improvement that are locally affordable and feasible.

[10] For more detailed information on each example mentioned, reference is made to the corresponding reports (Tujchneider, 2013; Zubari, 2013; Kataoka & Shivakoti, 2013; Braune & Adams, 2013; Chilton and Smidt, 2014). Numerous other examples can be found in publications prepared by GW-MATE for the World Bank and by IWMI; at TheWaterChannel's web portal; and in some text books (e.g. Shah, 2009; Margat and Van der Gun, 2013).

The rest of this chapter describes opportunities for improving groundwater governance, organized according to four components: information and knowledge; legal framework; policy and planning; and actors

Case histories that document progress in groundwater governance and successes in groundwater management and protection around the world are helpful in identifying opportunities and possible approaches for improving groundwater governance elsewhere. A selection of such opportunities, identified during different stages of the Groundwater Governance project, is briefly described in the following sections, as a prelude to a more comprehensive coverage in the two final outputs of the Groundwater Governance project: the Shared Vision and the Framework for Action.

5.2 Opportunities related to information, knowledge and awareness

Structural provisions for data and information

Assigning responsibility for assessments and monitoring to a single agency would ensure a coherent generation of data and information

In a number of countries, data and information on groundwater and its use are collected in a rather haphazard way, often fragmented and within projects of limited duration. Given the importance of adequate data and information for groundwater management and governance, a major step forward can be made in the form of structural provisions for data and information, by entrusting the related tasks to a specialised agency (e.g. a geological survey or a water resources agency) and thereby ensuring the required assessments and systematic monitoring are carried out.

Modern technologies for data acquisition and information management

Modern technologies offer efficient, low cost means of data acquisition and information management

Modern technologies such as automation in monitoring and in field surveys, telemetry, satellite based remote sensing, GIS, ICT, and use of the internet offer unprecedented opportunities to enhance data acquisition and data/information management by reducing the related cost, improving quality and/or creating new possibilities.

National or international projects and programmes

> *International or national programmes catalyze data acquisition, processing and interpretation*

Large international projects and programmes, either statutory (such as the EU Water Framework Directive and the derivative Groundwater Directive) or voluntary (e.g. regional UNESCO-ISARM) may be effective catalysts for the widespread acquisition, processing and interpretation of groundwater data relevant for groundwater management. A similar positive impact can be achieved by national programmes or procedures, such as the district-wise groundwater accounting applied in India by the Central Groundwater Board (CGWB) and state groundwater organizations, frequently updated in order to serve as a basis for decisions on incentives or disincentives for groundwater development (Box 5.1).

Box 5.1

User-focused and accessible groundwater information

With so many different partners needing to become involved in 'groundwater and development', user-focused and accessible information on the resource becomes imperative. The production of the first SADC Hydrogeological Map and Atlas had major benefits, among them, learning to share data and knowledge about a common resource. However, it was also a wakeup call regarding the availability and quality of data that was submitted by different countries. About 50% of countries do not yet have their own hydrogeological map, in all countries systematic monitoring is still in its infancy and a number of countries do not yet have functioning databases. It is difficult for aquifers and groundwater resources to be properly valued by decision-makers under these circumstances. The Groundwater Resources Information Project (GRIP) in South Africa, using water supply funding to augment the very limited hydrogeological service budget for this purpose, may be a pointer in the right direction.

Braune and Adams (2013) after Braune et al 2010

Cooperation with the private sector

Cooperation with private businesses can bring valuable experience, knowledge and data into the public domain

The mining industry, the oil and gas sector, the beverage and food industry, and several other segments of the private sector possess considerable but rarely shared information and knowledge on the geology and natural resources (including groundwater) of the subsurface. Cooperation between the public and private sector can result in synergies at field-study level, in learning from the private sector experience and in valuable data coming into the public domain.

Awareness raising and lobbying

Awareness-raising is essential to get political and stakeholder participation and buy-in, and can also bring political support on key high profile issues

Data and information related to groundwater are not only relevant for studies and planning, but also indispensable for the raising awareness on groundwater issues among those who could and should play an active role in groundwater governance. Awareness is essential to create the motivation for playing such a role and to get an idea in what direction to move. Groundwater users and other local stakeholders should understand basic cause-and-effect relationships in groundwater, which enables them to develop a positive and cooperative attitude towards groundwater management interventions. Sometimes, a 'passive' mode of developing awareness on groundwater (by absorbing supplied information) can be combined with more active modalities, such as participation in assessment and monitoring. At the level of high-level decision makers, awareness raising may evolve into lobbying for political support for active groundwater management and governance. Often it is helpful for lobbying to connect with locally relevant 'high-profile issues' such as acute water scarcity, underground hazardous waste disposal or 'fracking' for shale gas exploration.

5.3 Opportunities related to legal frameworks

Legal reforms

Legal reforms typically offer opportunities for improved governance

In many countries, laws related to groundwater are limited in scope, outdated, fragmented or otherwise unsatisfactory. In such cases, legal reforms offer opportunities to improve groundwater governance, but even when this has been done (Box 5.2), significant policy, institutional and capacity gaps may remain.

Bringing groundwater resources under public control

In many countries, there is a preference for declaring groundwater public property

The importance of groundwater for the entire society and the increasing competition for groundwater and its environmental services contribute to a growing body of opinion that community interests in groundwater should prevail over private interests. Enacting the corresponding legal provisions (such as declaring groundwater to be public property) will support this preference.

Box 5.2

Water sector reform in South Africa

Water sector reform in South Africa culminated in the Water Services Act, 1995 and the National Water Act (NWA), 1998. The NWA was built on IWRM principles and was to be implemented through decentralization. Groundwater is an integral part of the Act. However, governance of groundwater has not progressed as much as it should have and groundwater has remained an undervalued resource. Capacity to deal with groundwater is lacking across all management levels. A recent World Bank study found that provisions to control groundwater abstraction and pollution are weak or even non-existent at local levels. While national level technical, legal and institutional provisions are reasonable, cross-sector policy coordination is weak. Provisions for public participation, e.g. through the establishment of groundwater user associations, have not yet been enabled by central government.

Braune and Adams (2013)

Legally enforceable regulations

A legally enforceable regulatory regime is a powerful instrument of groundwater management

Regulations intended to influence individual behavior can only be enforced if they are based on the law. Consequently, dedicated legislation for such regulations (licensing water-well drilling and groundwater abstraction; charges for abstracted groundwater; charges for producing pollution; restrictions on land use in groundwater protection zones; general prohibitions; etc.) creates powerful groundwater management instruments.

Legal instruments for transboundary aquifers

Legal principles and guidelines illustrate pathways to cooperate on transboundary aquifers

Different legal instruments offer opportunities for improving cooperation between neighboring countries in relation to coordinated or joint management of shared aquifers. Endorsing the Draft Articles of the International Law on Transboundary Aquifers will contribute to the adoption of common and rational legal principles. Treaties and other legal tools may be used for more detailed and aquifer-specific arrangements.

5.4 Opportunities related to policy and planning

Aligning groundwater management with macro-policies

The value of groundwater to the nation can be increased if groundwater management is aligned with overall national policy objectives like poverty reduction and environmental protection

In many cases, groundwater management has evolved in a reactive mode, in response to observed or anticipated problems. Nevertheless, groundwater management can bear more fruit if it is more pro-active in achieving and sustaining a balanced set of services from groundwater. Opportunities for the latter are offered by aligning groundwater management with overall national objectives such as socio-economic development, agricultural production, poverty reduction and food security, and environmental protection), and vice versa.

Adopting suitable principles and approaches

Many sound principles are available to guide groundwater policy, such as the principle of sustainability and the 'polluter pays' principle

Concepts that have widely proven to be valuable components of groundwater management policy include the principle of sustainability, the precautionary principle and the 'polluter pays' principle. Other approaches that deserve to be considered include adaptive management, demand management in tandem with supply management, participatory management approaches and — last but not least – integrated water resources management (IWRM — see below), in which the previously mentioned approaches are often included.

Adopting IWRM and related approaches such as conjunctive management and MAR

IWRM principles *like participation, decentralization, an incentive structure reflecting water scarcity etc. and* ***management approaches*** *like conjunctive management can be incorporated into effective groundwater policies*

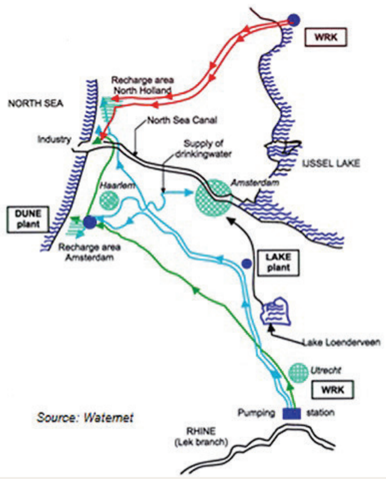
Integrated Water Resources Management (IWRM) offers the opportunity to account fully for the close interconnections between groundwater and surface water (both in a hydrological sense and as a source of water). In this context, conjunctive management of groundwater and surface water contributes to maximizing the overall benefit from the local water resources. Managed aquifer recharge (MAR) offers very significant opportunities world-wide for enhancing water availability. It deserves to be considered in particular in groundwater policies in water-scarce areas, but also provides opportunities where water resources are more plentiful. The long-term development of the water supply for Amsterdam (Box 5.3) can be highlighted as a successful example of the conjunctive use of surface water and groundwater, and also of joint management of water and land resources. Over its 150 year history this can be seen as an example in which groundwater governance has evolved into land and water governance and which builds on the thousand year tradition of the water boards (Chilton and Smidt, 2014). Modern groundwater governance in The Netherlands reflects changes in society and in perceptions of the environment, with groundwater and aquifers being considered as multifunctional resources for energy, water and waste disposal.

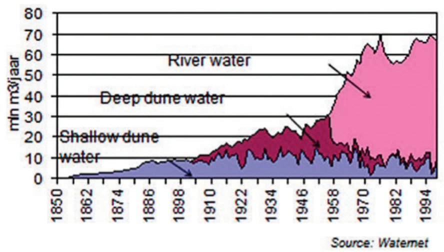
Box 5.3

Conjunctive use and artificial recharge for water supply in the coastal zone of the Netherlands

A water supply system for Amsterdam was established from 1853 by the construction of canals to draw water from the coastal dune systems. From 1903 these canals were replaced by wells, but the steadily increasing abstraction so close to the sea produced saline intrusion and the deteriorating quality of the pumped water began to threaten the operation of the systems after some thirty years.

The solution embarked on from 1953 was to pre-treat surface water from the Rhine near Utrecht, transport it 75 km (see map) and infiltrate it into the dunes. About 4 million people in the western part of The Netherlands are nowadays supplied with drinking water originating from a mixture of shallow and deep dune groundwater and infiltrated river water (see graph). Additional advantages of this approach were the creation of strategic water storage and recovery of groundwater levels to combat saline intrusion and to restore ecological and recreational functions.





An important governance provision which facilitated this development has been the merger between the water supply company, the regional water authority and the municipal water department. In the city of Amsterdam and surroundings one organization (Waternet) has been formed which manages both the natural water system and the water supply and sewerage systems. This has transformed the water companies into land AND water management companies.

Chilton and Smidt, 2014; after Smidt, 2013

Establishing policy and planning linkages with interrelated sectors

Depending on the level of institutional development and cooperation, there are important opportunities to recognize interactions with other sectors and to operationalize linkages like joint policy and planning

Groundwater abstraction and use, land use and land use practices, land use changes, the different uses of the subsurface space and resources (mining, energy, etc.): all have their own objectives and practices, but since they take place within the same spatial domain they are likely to interact. Awareness of these interactions offers opportunities for aligning policies and plans between these interrelated sectors, in order to eliminate or reduce potentially negative interferences (such as groundwater pollution by mining activities or by certain land-use practices). To what extent these policy and plan linkages are feasible in practice depends on the stage of advancement of the government institutions and their willingness to cooperate.

Introducing periodic and coherent groundwater management planning

Policy can mandate the preparation of area-specific management plans, and can also detail the steps in plan preparation

Systematic groundwater resources management needs to be based on a plan, tailor-made for the aquifers or areas concerned. Policy can define the groundwater planning steps to be made: their scope (strategic versus operational), hierarchy, frequency, institutional responsibilities and fund raising for implementation.

5.5 Opportunities related to actors

Enhancing political commitment for groundwater governance and management

Political commitment is essential, and lobbying for it can be accompanied by awareness-raising and by information products targeted at decision takers

This is of fundamental importance to put (and keep) groundwater sufficiently high on the agenda and to obtain the support (and means) needed for effective groundwater governance and management. It will require persistent lobbying fed by scientifically-sound information on issues and achievements.

Creating and developing leadership

> *Setting up a lead agency — or strengthening an existing one — is a key way to improve groundwater governance and management*

Success in groundwater governance and management requires leadership. If clear leadership is not yet present, then the government can make a major step forward by entrusting a suitable public agency with this role and to give it all support it needs to develop authority and capacity, and to carry out its tasks efficiently.

Institutional reforms

> *Institutional reforms can greatly improve groundwater management, especially if they clarify and consolidate mandates, empower agencies and bring management to the lowest feasible level*

Institutional reforms may be necessary to enhance the effectiveness and efficiency of groundwater management. These reforms may include: (a) a clearer and logical definition of the tasks and mandates in groundwater management and protection; (b) reduction or elimination of fragmentation of mandates, roles and tasks; and (c) establishing decentralised offices wherever necessary to make groundwater management and protection more effective. The example from Thailand summarized in Box 5.4 shows progressive and gradual development of groundwater governance by a responsible and capable institution in which the objectives of governance and management have changed according to social needs.

Involvement of the private sector

> *Increasing private sector involvement can strengthen governance, particularly in the sharing of knowledge and expertise and in partnerships in abstraction and pollution control*

Some segments of the private sector have traditionally played a role in groundwater development and management (water supply companies, drilling companies, pump manufacturers, etc.), but often there is scope to enhance their involvement in governance, for instance by sharing information. Many other segments of the private sector (e.g. oil and gas industry, mining industry, food and beverages industry) are potentially important actors — because of their information, knowledge, expertise and the impact of their activities on groundwater —, but up to now they have been little involved. Getting these segments of the private sector more involved is a promising step towards strengthening governance.

Box 5.4

Groundwater Governance and Management in Thailand

The history of groundwater management in Thailand began in the 1970s when the country started to suffer land subsidence in Bangkok caused by excessive groundwater abstraction. Increasing water demand for municipal water supply triggered large scale groundwater development in the mid-1950s, and then the industrial sector began to increase abstraction. To mitigate excessive abstraction the Thai government established the Groundwater Act in 1977 and strengthened regulations step by step in consideration of the stages of social development. Major measures introduced by the national government included the following: penalties and fines for non-compliance with the Act; designation of "critical zones" needing intensive measures; banning well drilling in "critical zones"; groundwater abstraction licensing; groundwater user charges and additional groundwater preservation charges; inspection of well-metering by private users; phasing-out of groundwater use by municipal water supply and development of alternative water sources. Groundwater monitoring has been also strengthened although there are budget constraints.

Among these measures, groundwater use and preservation charges were very effective in reducing abstraction. Because of the step-by-step but intensive approach, land subsidence has been mitigated and the objectives for sustainable groundwater management have been met, so that now the resource is protected from overexploitation and pollution while still providing substantial benefits.

The Department of Groundwater Resource (DGR), a part of the Department of Mineral Resources in the past, has been the institution responsible for groundwater management from its early stages up to the present day. The Groundwater Act entitled DGR to execute their administrative power to control groundwater abstraction. This clear responsibility of DGR is a factor in the success of groundwater management in Thailand. Currently, DGR is decentralizing responsibility to the lowest-level administrative units to strengthen local groundwater management.

Kataoka and Shivakoti (2013)

Involvement of local stakeholders

Stakeholder involvement can greatly enhance the effectiveness of groundwater management, and it can be encouraged through awareness-raising, local champions, and the establishment of organizations with stakeholder participation

Groundwater management should be largely intended to serve the interests of local stakeholders (both present and future generations) and many groundwater management measures will only be successful if local stakeholders cooperate (usually by complying with regulations and desired behavior). Therefore, involving local stakeholders is likely to have a very positive impact on the effectiveness of groundwater management. It is important to find modalities for motivating local stakeholders, to make use of their knowledge and to channel their energies. To this end, awareness raising programmes, the role of local 'champions' and the establishment of appropriate stakeholder organizations may be helpful. Box 5.5 refers to the example of the Low Llobregat in Spain.

Box 5.5

The Low Llobregat (Barcelona) Groundwater Users Association (CAUDLL)

This, the first such groundwater user association in Spain, was formed in 1975 when water was still a private domain under the 1876 Water Act. Favorable local factors encouraging this particular association at the start included the availability of detailed groundwater studies and the consequent awareness of the essential role of groundwater in the local economy. Most importantly, there was already a good degree of trust between the Water Administration and the water users, who at the time were dominantly water suppliers and industries rather than agriculture.

CUADLL was registered as a private body supported by the Water Administration and the municipal authorities. Its objectives were to protect private groundwater rights, secure water availability in periods of drought, and halt and reverse groundwater degradation.
The association's bye-laws allowed it to raise funds, punish wrong-doers and represent the water rights of its members.

The positive results included the control of new groundwater developments and reduction in groundwater abstraction, ending waste disposal in pits, and the establishment of monitoring programmes. The success of the approach encouraged most groundwater users in the Low Llobregat to join CUADLL. In addition, increased public investment came to the area which might not have happened otherwise.

Custodio, 2013

Success with groundwater WUAs in some areas of Spain was replicated elsewhere — but not everywhere, as the model fitted less well when there were very many users, or a lack of knowledge, or absence of leadership. The lesson is that the solution has to be adapted to the local context — and maybe also combined with other solutions

Although Spain has a long history of water user associations, with more than 7000 (mostly for surface water), there was no legal basis for groundwater users associations until the 1985 Water Act. Groundwater became a public domain, water authorities had an obligation to manage it, and water user associations became recognized as public bodies. This success became well known in other areas with heavy groundwater usage and serious deterioration. Although this encouraged the development of other water user associations, there were greater difficulties in dominantly agricultural areas with large numbers of users and right-holders, in areas with little existing groundwater knowledge or monitoring and, most importantly, where there was little interest or even resistance from the water authority. This example therefore illustrates that normally more than one of the opportunities summarized here need to come together to encourage better governance and management of groundwater.

Capacity building

Capacity building is key to groundwater management, particularly for lead agencies and key stakeholders

Good groundwater governance requires that all actors have the capacity to play their role adequately. Given the complexity of groundwater management, it is particularly important that this capacity is abundantly available within the organization entrusted with leadership regarding groundwater management. Where needed, capacity building programmes are a valuable and often indispensable investment to improve performance. The same will often apply to key persons of stakeholder organizations.

Funding and financing

Core funding, perhaps supplemented by cost recovery, is key to agency performance

Political commitment to groundwater governance should result in sufficient core funding for the key organizations to carry out their tasks properly. In addition, cost recovery based on financial contributions from groundwater users and polluters (or potential polluters) may provide an important opportunity to realize the budget required for groundwater management and protection.

Enhancing accountability, transparency and mutual trust

> *Accountability and transparency help the emergence of necessary cooperation and trust*

Enhancing accountability and transparency offers significant opportunities for improved cooperation and developing mutual trust among the many actors in groundwater governance.

Role of international organizations and partnerships

> *International organizations and partnerships offer significant opportunities to enhance groundwater governance*

Often international organizations and partnerships can not only provide finance but they can also initiate or catalyze the processes of change, contribute to acquiring political support or produce added value in projects and capacity-building programmes.

> *Success stories and best practices can indicate opportunities to improve governance, but often more than one opportunity may need to present itself for the improvements to really work*

As discussed at the beginning of this chapter, success stories and identified best practices are a valuable source of inspiration for addressing groundwater governance gaps and flaws. Nevertheless, a critical approach is necessary to verify whether reported successes are sustainable, and to assess whether and under which conditions they are replicable. All of the examples highlighted above indicate that one specific new opportunity may provide the initiative or catalyst for improved governance of groundwater. However, one or more often several of the other opportunities outlined above may need to present themselves if better governance and management of groundwater is to be implemented and sustained.

Table 5.2

Selected identified opportunities for improving groundwater governance

Category	Opportunities
Information, knowledge and awareness	• Structural provisions for data and information • Modern technologies for data acquisition and information management • National or international projects and programmes • Cooperation with the private sector • Awareness raising and lobbying
Legal frameworks	• Legal reforms • Bringing groundwater resources under public control • Legally enforceable regulations • Legal instruments for transboundary aquifers
Policy and planning	• Aligning groundwater management with macro-policies • Adopting suitable principles and approaches • Adopting IWRM and related approaches (conjunctive management, MAR) • Establishing policy and planning linkages with interrelated sectors • Introducing periodic and coherent groundwater management planning
Actors	• Enhancing political commitment • Creating and developing leadership • Institutional reforms • Involvement of the private sector • Involvement of local stakeholders • Capacity building • Funding and financing • Enhancing accountability, transparency and mutual trust • The role of international organizations and partnerships

6. Recommended pathways toward improved groundwater governance

6.1 Adoption of principles for governance of groundwater

Variable outcomes and missed opportunities in groundwater management underline the shortcomings of groundwater governance and its essential differences from the governance of surface water — but also the need for integrated management of the whole hydrological cycle

A framework to help strengthen groundwater governance in countries across the globe needs a set of guiding principles that can find common acceptance in all aquifer settings where groundwater development and protection are taking place. The inherent character of groundwater presents a set of quite unique governance challenges and it can be argued that attempts at influencing millions of individual decisions to use or abuse groundwater have failed to take hold because these challenges have not been adequately addressed.

Past attempts to regulate and manage groundwater as just another natural resource have informed us what not to do — but also given us some indication of where to start. For instance, some environmental reporting requirements are now prompting more inclusive assessments of groundwater status and risks to economic, social and environmental services derived from groundwater. But at the same time opportunities for conjunctive use and conjunctive management are being missed — as the necessary understanding of surface water-groundwater interactions has lagged and the structural role of groundwater in integrated water resource management has been largely ignored. In this sense, explicit recognition of groundwater in water governance debates is hard to find. The emphasis remains centred on surface water-dominated 'hydraulic' administrations where investments are more supply-driven, 'lumpy' and visible.

> *Thus commonly-accepted water governance principles — equitable access, accountability, transparency, participation, integration — all apply, but they need to be adapted to the specific character of groundwater — and to be supplemented by the precautionary principle and a knowledge management principle*

Therefore, the basic or foundational water governance principles of equitable access, accountability, transparency, user participation and the requirement to integrate assessments and management responses (Varady *et al*, 2012) still apply but may need 'enhancing' to make them more applicable to groundwater use and address the 'governance gaps' identified in chapter 4. In addition there may be a set specific principles of governance that relate to groundwater, based on the presumption that patterns and intensity of groundwater use will need to be sustained in the future. These groundwater governance principles are listed with brief comments below. All these principles are expected to apply at all levels of management — from local to global.

Equitable access: **direct users of aquifers protected in the public interest**

Where groundwater dependency is high — to meet basic needs or secure livelihoods — continued access to groundwater in underlying aquifers will need to be protected in the public interest. Some regional laws (e.g. the provisions of Sharia law) provide for this out of long-held tradition that recognizes water scarcity as a permanent factor in human existence. At the other extreme, a permissive approach to groundwater development can simply allow elite capture through drilling and pumping technology that may not be available to poorer users. These rights in use (often expressed as *de minimis* uses in modern water law) will need to be protected in all cases.

Sustainability: **incorporate aquifer response time and renewability**

A general notion of 'sustainability' in terms of simple recharge and withdrawal budgets is not sufficient. A more informed appreciation of how governance arrangements can be used to manage or relax aquifers under pressure is called for. These will necessarily involve quite subjective criteria as to what social, economic and environmental consequences are acceptable for a particular system of groundwater supply and use. In addition, the slow movement of groundwater and the time over which aquifers respond to development or become imprinted with pollution, and therefore also the **time** they take to respond to management actions, presents a particular governance challenge when considering long term sustainability of groundwater use. Finally, the development of non-renewable groundwater presents a specific governance challenge since decisions over planned depletion have to be made based on policy goals for socio-economic development.

Transparency: **making groundwater and groundwater management visible**

Access to clearly presented **information** is a fundamental pre-requisite for any water governance, but needs special effort in the case of groundwater, as it is unseen and hard to characterize. In addition, groundwater management by its nature is highly decentralized – essentially each well owner is a groundwater manager and any activity above an aquifer is a pollution threat. Hence transparency over the state of the resource and the processes though which users and managers are bound at the local level are fundamental. For example, the **communication channels** and the **rules and means for negotiating decisions** over groundwater use and aquifer protection all need to be transparent.

Participation and representation: **engage with groundwater stakeholders at aquifer scale**

Engagement with users and polluters at aquifer scale is essential in order to monitor and agree drawdown limits or acceptable limits to pollution. To be inclusive at every stage and level of the governance process in aquifer development and protection has proved a challenge for many governments and water agencies. However, there is now evidence that, where institutions and mechanisms of inclusion and participation can be established, the clear presentation of locally relevant groundwater information can be combined with participatory monitoring of aquifer state to agree acceptable levels of drawdown or groundwater quality. Given the hidden and sometimes complex nature of groundwater occurrences, the issue of who is qualified to represent users and groundwater resource managers needs to be established at an early stage.

Accountability: stress economic benefits and consequences of groundwater use

If a principle of equitable access is to be adopted, determining who benefits and who stands to lose as a result of groundwater use is a basic requirement. It has been stated that more could be done to stress the social and economic benefits of groundwater. However this realization is only likely to have impact if accompanied by an account of the costs or consequences of use and a system of rules that effects compliance. This includes the impacts of poor drilling practice and borehole construction and the adherence to commonly accepted norms and standards, along with a system to allocate groundwater use in an equitable fashion.

More problematic is the identification of those who cause groundwater pollution but do not use groundwater. Recognition of the polluter-pays principle may work well for water users, but may prove difficult to apply and even more difficult to extend to those who change land-use, apply agro-chemicals or excavate and drill into aquifers. The application of tests or criteria for determining who is accountable for groundwater use and aquifer protection and agreement on a system of compliance are likely to form part of an approach toward good groundwater governance.

Functional integration with water policy & management

If groundwater governance is a neglected area of water policy, improved governance is only likely to occur if groundwater management can be integrated with overall water policy and management processes. An explicit shift from conjunctive use to conjunctive management (Evans *et al*, 2012) is expected to yield benefits where the buffering and storage advantages of groundwater can be realized across landscapes and economic sectors. In this sense groundwater management needs to become more expert in playing with groundwater use in conjunction with surface water supplies and wastewater streams through imaginative use of economic and technical instruments (such as payment for environmental services, wastewater re-use and trading of fresh groundwater for wastewater as an irrigation resource) and imaginative collaboration with other water sector players.

Precautionary principle – protecting aquifer water quality and assuring recharge

The vulnerability of aquifer systems to surface processes and the human encroachment of the earth's crust has been well established — and further analysis of processes and impacts should not be an excuse for inaction. It makes sound economic and public health sense to identify and protect recharge areas — and recharge processes. For instance it is hard to improve upon natural processes of recharge for augmenting groundwater and improving water quality, and maintaining the integrity of the land-aquifer coupling will continue be a key concern in a crowded world. However, it also makes sense to regulate the direct injection of pollutants and the disruption of aquifer fabric on the basis of the precautionary principle in the knowledge that such interference may prove to have impacts that are irreversible. This principle will be particularly important to the Small Islands Developing States (SIDS) in the Caribbean and Pacific regions where the available land area for waste disposal and options for obtaining alternative sources of water are extremely limited.

Knowledge management principle

A common plea made to hydrogeologists by non-hydrogeologists is that more could be done to popularize groundwater information and groundwater dynamics. The problem is that hydrogeology can be very complicated — detailed aquifer system behavior in relation to supply (recharge) and demand (abstraction) has to be modelled to fully appreciate storage depletion and quality changes over time. However, the challenge of presenting these results to the layman is there — the implications of these sophisticated interpretations need to get across to groundwater users to the point where groundwater use is moderated and aquifer protection is advanced.

Beyond the basic dissemination of groundwater information, the use of groundwater information and knowledge by groundwater managers to assess the risks of groundwater depletion and pollution will be essential in assigning and applying groundwater management criteria. In the case of groundwater (as opposed to surface water) it is essential to anticipate the evolution of groundwater quality and hydraulic state over time. An obligation to promote the use of groundwater knowledge is therefore seen as a fundamental principle underpinning groundwater governance.

6.2 Desirable Institutional Responses

The components of an institutional response to groundwater management challenges are clear — information, an institutional 'home', a working system of governance arrangements that serve a public interest, the provision of technical support — and political viability

Removing barriers between groundwater science and policy makers cannot be done without making the invisible somehow 'visible' and the scale and intensity of current and future impacts apparent. How such material is presented by the hydrogeological community together with the range of multi-disciplinary science that is associated with its development and management (from epidemiology to power utility management) is important to give groundwater governance an institutional 'home' and demonstrate that there is an economic return for investing in groundwater governance. All this hinges on a working system of mutually acceptable arrangements between users and polluters to moderate behavior and act in the local public interest. In the absence of any formal institutional response, such arrangements may occur spontaneously as local aquifer communities react to commonly felt threats or impacts. However such is the invisible nature of the resource that technical guidance is needed when problems emerge — and preferably before. But, even when an institutional framework for natural resource governance is in place, the lack of any political commitment to implement it may continue to frustrate the achievement of agreed outcomes. To this extent the early identification of the political viability for introducing a progressive system of groundwater governance is needed.

Making groundwater information accessible

> *For governance to work, a necessary — but not sufficient — condition is that groundwater information has to be accessible and usable by those who have a direct impact on groundwater quantity and quality*

The advanced hydrogeological knowledge that has been gained in studying aquifer responses to human demands will continue to be essential but piercing the consciousness of policy makers and water managers alike still remains a challenge. The absence or lack of clear presentation of hydrogeological information can often mean that essential information on the right scale for groundwater-related risks to development or environmental services are simply not getting through. But for governance to work this groundwater information has to be accessible and usable by those who have a direct impact on groundwater quantity and quality. For instance, the APFAMGS project in Andhra Pradesh (Box 3.1, Kataoka and Shivakoti, 2013) had some success in helping both farmers and potable water users in village communities to manage inter-annual groundwater level fluctuations in local aquifers — largely by self-monitoring of pumped boreholes. While this is necessary, it is not likely to be sufficient by itself to prompt self-regulation by users to the extent that groundwater levels can be stabilized, as in the case of the Guanajuato State technical water councils (COTAS) reported by Wester *et al* (2011) where more proactive mechanisms for enforcement of groundwater regulations and promotion of transparency and accountability are seen as necessary complements.

Making an institutional home for groundwater

Assigning clear responsibility for groundwater management is important — dedicated groundwater management agencies with access to good information and knowledge are the best approach, but many locally-evolved variants are possible

Beyond the information hurdle, simply making an institutional 'home' for groundwater amongst related water and environmental institutions still appears to be difficult — particularly when dealing with urban groundwater governance (Thematic Paper 3). Traditionally, geological surveys or agencies have informed water resource and environmental regulators. Only a few countries have attempted to set up dedicated groundwater management agencies. India, for example, has had a Central Groundwater Board since 1970 and recently introduced a Central Groundwater Authority in an attempt to co-opt State Governments in promoting more active groundwater regulation. Clearly in a large country such as India, the scale and diversity of groundwater challenges is unprecedented. At the other end of the spectrum, many local initiatives related to groundwater management, such as recharge movements cited by Shah (2007) may arise in an information vacuum or without up to date scientific validation of their efforts.

Removing constraints

Approaches to regulating groundwater have proved highly problematic and have often not reached their objective — thus judging whether to regulate groundwater use at all, and if so, determining precisely where to start needs to be carefully thought through

While the points above have suggested areas where a positive approach can support groundwater governance, it is also reasonable to ask if there are any institutional constraints to governance that could be removed. Many seemingly straightforward approaches to natural resource governance — including direct and indirect 'pricing' — may impose a rigid set of institutional instruments that are not politically viable and hence produce no governance solution. Adherence to abstraction licence quotas from a central agency or reform of electricity tariffs to rural areas may be things that just run into a political roadblock and do not obtain a political constituency for aquifer conservation or protection. More acceptable approaches, including amnesties on 'illegal' boreholes may have more positive impact if they bring the scale of the problem to light and set the basis for mutually acceptable solutions.

Facilitating investment in groundwater management

Interest and investment in groundwater governance is typically limited and sporadic

Identifying and facilitating investment in groundwater management has rarely become a priority or habit. Once a drought or groundwater pollution event has passed, interest tends to decline and institutions that were once considered vital in solving a groundwater resource problem are no longer fashionable, even if the risk persists. In many senses it is the lack of specific and persistent institutional responses to groundwater governance that has constrained efforts conserve and protect aquifers (Thematic Paper 5).

The best management unit may be the local level where interests and problems can be identified and responses can be agreed and applied — although even here there may be conflicts between, say, local agricultural use and transfer to meet municipal needs

The governance challenge tends to be lumped with those of water governance in general. This is certainly necessary, but not sufficient. The intensity of local demand for groundwater services is such that there is a lot of private interest which is occasionally mobilized into a public interest matter, by which time it may be too late to resolve. It could be argued that national and regional initiatives such as the specific groundwater pollution directives embedded in the EU Water Framework Directive — or the USA's CERCLA Superfund — are simply too late to remediate aquifer services even if they are successful in preventing further degradation. Hence it is probably necessary to establish the specific policy and investment 'space' for groundwater management at scales suited to the grouping of groundwater interests and the effectiveness of mitigation measures. But even here it can be realized that the interests of local livelihoods supported through access to groundwater may be incompatible with the need to protect an extensive aquifer to provide municipal supply. In this way, the governance and investment challenge is not as straightforward as financing river basin surface water resource development and management. Tailoring the investment space for groundwater governance is beset by the low-intensity but highly distributed nature of groundwater conservation and aquifer protection measures.

6.3 Promoting viable institutional strategies:

There are no easy way to promote groundwater governance but there are at least some good starting points

It has already been noted that the governance of groundwater use can be promoted through a combination of initiatives appropriate to the hydrogeological setting and socio-economic conditions above an aquifer. Certain institutional 'conditions' as noted by Ostrom (2001) and the application of criteria Blomquist (1992) also appear to be necessary in some cases even if the institutional responses and eventual outcomes are diverse. So there appear to be no quick wins. What types of strategy have become apparent? Listed below is a sample of institutional strategies that can be identified from the available evidence. It is not exhaustive or inclusive of all the local hydrogeological and socio-economic conditions that exist, but suggests some starting points to improve the state of groundwater governance:

- Engaging with users at aquifer scales and defining mutually acceptable levels of depletion and degradation
- Anticipating the evolution of groundwater quality and migration of natural pollutants (arsenic, fluoride etc…)
- Accounting for economic impacts and spreading production and environmental risks
- What to do when access to groundwater disappears
- Investing in governance take account of specific regional risks (conditioned by hydrogeology)

The evidence from the formation of groundwater management committees in Andhra Pradesh (Das & Burke, 2013) gives some indication of what can be done to reverse trends in groundwater exploitation (and outward migration) when local annually recharged aquifers are implicated. On a broader national scale, contractual instruments to regulate the management of specific aquifers appear to be making progress, for instance the 'contrats de nappe' employed in Morocco (AFD, 2014)

Governance — and management — need to be realistic, based on understanding of both hydrogeology and socio-economy — as well as of political realities

Groundwater development and regulation may be subject to 'unreasonable expectations' if policy is not well informed. This might apply to expectations that low yielding basement complex

aquifers can furnish adequate supplies for irrigation or equally that curbs are put on development of highly productive karst aquifers if recharge processes are not well understood.
There is a case for a balanced investment policy that recognizes the essential differences between shallow and deep groundwater circulation — and the political viability of changing user behavior.

Engaging with users at aquifer scales

Management rules at the local level can be simple — for example, agreeing acceptable drawdown levels between groups of aquifer users

The flow of groundwater through aquifers may be complex, but management rules can be simple such as agreeing maximum acceptable drawdowns in pumped wells or simply banning the storage and application of pesticides across an aquifer that furnishes potable water supplies. These can be things that a well identified community of groundwater users can agree upon if basic information is made available and explained (Thematic Paper 7).

Stakeholder engagement from the outset is vital

How groundwater managers engage with user communities at the outset is important. If water resource agencies have failed to 'socialize' groundwater because of technical preferences for hydraulic management, then this might require a quiet revolution within the agency to establish a legitimate and respected platform to engage groundwater users. Equally, an initiative could be promoted as an autonomous, self-governing adaptation in which case it may make sense for a water agency to simply get out of the way or facilitate the adaptation.

Anticipating the evolution of groundwater quality

Quality deterioration is a slow process and responsibility is difficult to attribute

Protecting aquifers from surface pollution, the migration of low quality water or the mobilization of natural pollutants such as arsenic is perhaps the most technically challenging strategy to put in place (Thematic Paper 1). Not only is there a burden of proof (who caused the degradation) when a damaging level of pollution becomes apparent, but anticipating the aquifer vulnerability **ahead** of the damage to public health and reduction of economic output can be counter-productive. Hydrogeologists many lose public confidence if they cry 'wolf' too often. For these reasons, adoption of risk-based approaches to groundwater pollution, such as those instituted under the EU Water Framework can signal and rank probabilities of degradation in a consistent and comprehensive fashion.

Defining mutually acceptable levels of depletion and degradation

Once a manageable unit has been identified and the procedures for stakeholder involvement are working, it should be possible to agree on objectives and to work towards them — although approaches, objectives and management changes will vary considerably between locations

Once a point of entry for improved groundwater governance is established, the promotion of specific groundwater objectives that address specific livelihood concerns — and are politically viable — becomes possible. With clearly bounded communities of users on small aquifers or aquifer blocks the task can be straightforward, but as the aquifer scale increases along with an increase in the number of users and of uses that encompass a diversity of economic and social interests, the task becomes complex. How it is approached in highly dispersed rural communities on thin discontinuous aquifers will be very different from the approach taken for a rapidly expanding urban area reliant upon a set of deep aquifers and aquicludes that gives a range of supply, disposal and geotechnical services.

Spreading production and environmental risks

*The costs and benefits of groundwater management action — such as depletion or inter-sectoral transfer — need to be analyzed in **economic** terms, taking account of opportunity costs, externalities etc.*

In general more analytical effort could be made regarding the increases in groundwater development costs (i.e. as a result of prolonged and non-sustainable extraction), transfer of surface water from rural (irrigation) to urban (domestic) uses, and reductions of water availability due to severe drought and scarcity (Thematic Paper 9). This requires moving from a strict financial perspective (extraction costs, financial profitability in irrigation, financial cost of bulk water for water utilities, etc.), which is essential anyway, to a more comprehensive economic perspective that takes account of externalities and multiplier effects on macroeconomic variables — that is, a formal efficiency analysis — and a more complex analysis of social (i.e. equity) concerns. Economic analysis could also be able to shed some light on the economic cost of some management decisions within an overexploitation context: inter-basin transfers, compensation for potential (financial) losses to those farmers that have already contributed to overexploitation, public purchase of water rights etc.

What to do when access to groundwater disappears

Exhaustion of aquifers can lead to out-migration from rural areas or entail high costs in water transfers from other sources — and these impacts and related costs should be evaluated in advance when management decisions can still affect outcomes

At the limit of economic pumping or complete salinization of accessible groundwater, agricultural groundwater users may be able to move to other rural areas to practice farming or exit the rural economy altogether. Mixtures of this outmigration and partial return once aquifers have recovered have been observed in South Asia without a wholesale breakdown of rural economies. Options for urban communities who are reliant on local groundwater sources (Thematic Paper 2) are less flexible and imports of alternative water supplies have become standard solutions in post-industrial economies such as California as much as rapidly urbanizing developing countries in South Asia. At this stage it may also be important to look toward the frontiers of groundwater research and aquifer use (Thematic Paper 10) and consider provisions for the governance of these 'exotic' uses of aquifers before unintended environmental or public health impacts occur. For these reasons, it makes sense to always go back to the basics of aquifer recharge, storage and discharge (Thematic Paper 3) to evaluate the long-term impacts of development and judge where management of these processes, including conjunctive management (Thematic Paper 2), is viable in both technical and political terms.

Structuring investment in groundwater governance

Although governance arrangements will vary enormously according to local conditions and constraints, several simple steps to setting up a practical governance framework can be suggested — pulling together information to establish stakeholders' interests, identifying a lead agency, defining rights and incentives, and ensuring transparency and accountability

The regional differentiation is important to stress. Groundwater governance targets will be conditioned as much by hydrogeological realties as expanding human demand for groundwater and related aquifer services. Being aware of the structural role of groundwater in economic development and how its use is shaping economic transitions may be higher priority for semi-arid countries seeking to stabilize rural economies (Thematic Paper 9). But even in humid settings where water scarcity does not appear to be a constraint for development, reliance upon a range of aquifer services for continued urban expansion can be locally intense. In either case, management of groundwater and aquifer services to sustain these uses will need a practical governance framework. Depending on local conditions, some relatively easy first steps can be suggested:

- pull together aquifer and groundwater use information into a coherent, transparent baseline to establish patterns of groundwater dependency
- make an institutional home for groundwater governance
- establish user communities and their rights in groundwater use where management is required
- make transparency and accountability in groundwater supply and demand a requirement

6.4 Anticipating Climate Change

Climate change is likely to affect the hydrological cycle and aquifer circulation, land use, and patterns of recharge and pollution

The vulnerability of groundwater systems across different continents has recently been assessed (Thematic Paper 12) in relation to existing utilization, the effects of climate change on recharge and sea-level rise, and wealth; this is summarized in Table 6.1. The Global Groundwater Governance Project (Thematic Paper 12) reviewed the range of groundwater-related impacts that can be anticipated and the types of adaptation measures that are likely to be appropriate. The specific implications for groundwater are echoed in FAO (2010) as they relate to two main impacts: (1) altered hydrological cycles and aquifer circulation; and (2) shifts in land use and patterns of recharge and pollution. As aquifers in humid and even semi-arid zones are intimately connected to streams and other water bodies, changes in aquifer level can lead to changes in network behavior, such as the reversal from recharge from a river to discharge into it and vice versa.

Accelerated hydrological cycles and groundwater circulation

Groundwater serves to buffer annual and seasonal variations in rainfall and runoff, and requires increasingly careful management for sustainable use

Aquifers have an important strategic value as accessible over-year stores of water in a relatively stable condition without evaporation losses. In addition, percolating water is naturally de-contaminated along diffuse recharge and circulation pathways. The development

Table 6.1

Preliminary Assessment of Susceptibility of Groundwater in World Bank Regions to Climate Change

	Sensitivity	Exposure		Adaptive capacity	
World Bank region	Utilization of groundwater	Climate change impact on recharge	SLR[1] & storm surge exposure	Per capita GNI[1]	Vulnerability[2]
East Asia & Pacific	Moderate	Increase	Medium	Moderate	Moderate
Europe & Central Asia	Low	Increase	Low	High	Low
Latin America & Caribbean	Moderate	Reduction	Medium	Moderate	Moderate
Middle East & North Africa	High	Uncertain	Low	Moderate	Moderate
South Asia	Moderate	Negligible	High	Low	High
Africa	Moderate	Reduction	Low	Low	High

SLR – sea level rise; GNI – gross national income (in $US)
Vulnerability assessed from the sum of average of sensitivity and exposure ratings and adaptive capacity rating.
Groundwater utilization – low (2), moderate (4), high (6)
Impact on recharge – increase (2), uncertain/negligible (4), reduction (6)
SLR exposure – low (1), medium (2), high (3)
Per capita GNI – low (6), moderate (4), high (2) – relative to each other
Low vulnerability (‹6), Moderate (6-9), High (›9)

(Source: Thematic Paper 12)

of groundwater has therefore been an important structural adaptation to drought and is likely to be more so in the future. Clearly this character of groundwater is of more strategic importance to potable water supply than agriculture since agriculture is generally indifferent to the quality of most freshwater stored in accessible aquifers. However, agriculture has been quick to exploit groundwater circulation and now accounts for over 80 percent of all groundwater withdrawals (Siebert *et al.*, 2010). Patterns of groundwater recharge drive groundwater circulation and are determined both by rainfall (direct recharge) and transmission losses along watercourses (indirect recharge). When localized alluvial aquifers are annually replenished, they have good connection to surface flows and are dependent on stream flow (duration and stage) and surface water bodies for recharge. Groundwater in such systems serves to buffer annual and seasonal variations in rainfall and runoff, and will require increasingly careful management for sustainable use.

> *Changes in rainfall and run-off patterns are unpredictable and vary by location — but groundwater will be a key element in building resilience*

How are arrangements for groundwater governance likely to change as a result of this? First groundwater as a means of building resilience to reduced recharge and water scarcity will be a first order response, but there are other cases where climate change may present niches of enhanced aquifer recharge. The important point to recognise is that while levels of risk to existing hydrological regimes are broadly predictable, the uncertainty of climate change on rainfall/runoff patterns is such that precise projects may be impossible. While temperature impacts and increased ET can be expected with a high degree of certainty, rainfall projections may simply add 'noise' with the result that no conclusive modelling of rainfall-runoff projections can be expected (Chiew *et al*, 2010).

Changing patterns of land use and recharge

> *Changes in patterns of land use associated with climate change — for example, forest clearance — will also affect recharge*

The influence of land use on groundwater recharge is generally well documented in post-industrial economies where groundwater is an important component of potable supply (Thematic Paper 4). However, it will be important to understand the relative importance of base flow versus flood events in long-term recharge of alluvial aquifers. The role of forests in raising base flow, even while reducing overall runoff, needs more understanding. A good and clear understanding of the likely impacts of climate change on groundwater circulation is therefore very valuable, but is unfortunately bedevilled by the general uncertainty surrounding the prediction of rainfall and runoff under current conditions (Scanlon *et al.*, 2006). The sustainability of groundwater use is determined by the rates of abstraction and recharge, and also quality of the recharge water. In broad terms, recharge is expected to be high where rainfall is high and vice versa. Recharge will also increase where permafrost thaws and may increase when runoff increases, particularly if over-bank flood events occur more frequently. Although there is a broad correlation between recharge rate and rainfall, replenishment in a specific aquifer is further governed by geology, topography and land use. Forested catchments tend to have lower rates of aquifer recharge than agricultural and cleared catchments, and afforestation, although desirable to sequester CO_2, will probably reduce recharge; this would require compensation if groundwater resources are to be maintained.

6.5 Anticipating the impact of technologies and groundwater 'frontiers'

Geophysical exploration

Scientific advances are creating the potential to acquire much better hydrogeological information but this may not necessarily feed into groundwater management decisions

The advances in earth science remote sensing and the application of petroleum exploration techniques to solve hydrogeological 'unknowns' (from rock characterization to geo-statistical appraisal of aquifer systems) can be expected to advance the precision and resolution of hydrogeological information. The degree to which this new information is **interpreted** to frame basic resource allocation questions remains to be seen. Generally, the application of **high resolution** geophysical surveys will remain expensive in relation to the budgets given for groundwater exploration and management. When public domain data such as the gravity anomaly data derived from the GRACE mission has become available, careful calibration and validation is required before the results can be applied at aquifer scale. (Doll *et al.* in press)

Drilling and pumping technology

Drilling technology is constantly improving — but regulation remains a challenge

The application of progressively advanced drilling technology is expected to make an impact in high value water well drilling at depth or in difficult (mixed matrix) geology while traditional methods of drilling (including manual methods, jetting, cable-tool, rotary, down-hole-hammer) will continue to be applicable. Costs of drilling (and hence access by private users) are only expected to come down where competitive markets in drilling can develop. Licensing of drilling contractors and obligations to file drilling reports with regulators are the corollary to open access to drilling technology — and the assurance of professional drilling and borehole construction standards. But in many cases the drilling industry is not regulated and opportunities for getting away with poor construction standards abound. In these cases, the adoption of national codes of practice for drilling and borehole construction makes sense.

Improvements in the efficiency of pumping equipment will make groundwater abstraction easier and cheaper, and regulation will struggle to keep pace, unless collaborative or self-regulating regimes can be agreed

The limits of pumping depth and pump capacity are not expected to change significantly in the foreseeable future (Thematic Paper 8). What will change is the efficiency and reliability of groundwater pumping equipment — including the efficiency of solar panels and wind turbines. This will only intensify the pumping potential in both deep and shallow aquifers and extend areas of low intensity abstraction (though alternative energy sources). But apart from making the pumping technology more energy efficient and reliable, it is the access to technology and its responsible use in relation to aquifer characteristics that presents a specific governance challenge. In this respect, regulation of groundwater pumping behavior can be expected to emerge as an eventual target of governance even if it has proved hard to achieve compliance at present.

Further impacts on the built environment

Issues of aquifer management for urban areas are likely to intensify, including geo-technical stability, quality management in the hinterland, and the use of exhausted peri-urban aquifers as waste dumps

Subsidence as a result of aquifer drainage will continue to afflict urban and agricultural infrastructure and may be combined with groundwater rise in urban areas where industrial pumping has ceased and aquifer recovery has occurred (Thematic Paper 3). The institutional 'handle' on intensive agricultural use has been well explored, but the wholesale management of aquifers underlying urban areas may go beyond simple urban land use planning problem and involve management of aquifer zones in the urban hinterland as the risks to pollution of urban water supply and geotechnical stability become apparent. The institutions implicated in dealing with these multi-functional aquifers can be diverse with no clear agency 'lead' But what happens to groundwater quantity and quality in these zones of 'transition' are likely to have an **unprecedented** complex of socio-economic and environmental impacts. If there are options to import surface water and abandon groundwater sources then peri-urban aquifers may simply become accepted repositories of waste. But in many cases, particularly for the urban poor relying on self-supply, the depth at which groundwater can be obtained and its quality will remain critical livelihood issues.

Implications of crustal encroachment

Issues regarding interference with aquifers from other sub-surface activities are becoming more important

Use of aquifers and adjacent geological structures for abstraction of shale gas (hydro-fracturing) or storage of gas (Evans and Chadwick, 2009) are now expanding the 'managed' underground space beyond the standard set of urban utilities and basement/bunker construction (Thematic Paper 10). At the same time, the use of groundwater circulation for geothermal energy and aquifers for carbon sequestration all involve decisions about who has the right to inject, withdraw and circulate groundwater.

Evolution of environmental instruments and aquifer protection

The potential impact of sequestering carbon in aquifers deserves study

The significance of global environmental agreements and treaties cannot be ignored.The 1992 UN Convention on Watercourses and the Draft Articles on Transboundary Groundwater may be explicit about groundwater as part of transboundary flow systems, the impact of other environmental treaties bears consideration, for instance the impact of carbon trading schemes under the Kyoto Protocol encouraging the sequestration of carbon in aquifers.

6.6 Stressing the Benefits of Good Governance

Livelihoods outcomes and groundwater transactions

Equity and welfare benefits from groundwater are considerable — but they need to be protected under governance arrangements

The equity and welfare afforded by access to groundwater cannot be under-estimated, but is often overlooked in economic terms. The social and public health benefits deriving from what many water legislations recognize as 'de minimis' use are significant — but only as long as these use rights are protected and combined with aquifer protection measures.
The complex micro-economic transactions surrounding groundwater use have been documented particularly well in India — from the seminal work of Shah (1993) onward.

Groundwater markets have emerged in several countries but their generalization is limited by inherent challenges — defining water rights, establishing a regulatory framework, accounting for resource costs and externalities

A formal groundwater market is an arrangement in which groundwater right holders trade their rights (either within the market itself or with outside parties). There is no single market model — and the experience is limited to just three countries (Australia, Chile and the USA), but the characteristics for market design will depend on (a) the prevailing hydrogeological regime, (b) the previous history of informal trading and/or rights, (c) the types and numbers of groundwater right holders and users and (d) the physical arrangements for moving water between users. Research into the water market initiatives found that there was no explicit distinction between surface and groundwater right allocation, that legal provisions were not able to take account of impacts outside the markets, and that transaction costs tend to be overlooked (Thematic Paper 10).

Macro-economic outcomes and setting the incentive structure

The structural role of groundwater in a national economy is rarely appreciated

The specific economic dependency on groundwater has not been systematically analyzed or incorporated explicitly in national resources accounts (for example SEEAW). The economic literature on groundwater is predominantly of a partial equilibrium type (Thematic Paper 10) assuming the rest of the economy can be treated as a set of parameters. Working toward general equilibrium solutions would not seem appropriate unless groundwater values in all economic sectors can be adequately captured. The instances where groundwater has been directly related to GDP are limited (e.g. Ruta, 2005).

The incentive structure can be used to improve efficiency, although this may not lead to real water savings

Economic instruments can provide incentives to allocate and/or use groundwater more efficiently although such efficiency, tends to be analyzed (if at all) from a static perspective and also de-linked from equity. There are two main policy measures to reduce demand — direct pricing through resource abstraction fees and indirect pricing through increasing energy tariffs. These have to be set against positive economic incentives to change production patterns and subsidies for efficient use such as improved irrigation systems or water conservation programs. It is not certain that such attempts to manage demand for groundwater lead to actual water savings or the relaxation of abstraction demand upon aquifers (Ward, 2007).

Economic assessments of groundwater need to recognize both the benefit of current abstractions for production or water supply and the value of leaving water in the ground either to maintain quality, aquifer health and ecosystem services or for the benefit of future generations

While the renewable nature of water resources is often assumed, this may not apply at all aquifer scales and over all time — aquifers can go through periods of non-replenishment. From a welfare perspective, there is an argument that the optimization of groundwater use should be linked to dynamic efficiency (and not just static), and intergenerational equity. This is linked to physical return flows, which are not always taken into account in some water legislations and management approaches. There is a need to distinguish and possibly reconcile two different economic interpretation of groundwater resources. Much emphasis has been placed from a management perspective on the 'flow' dimension (income generated from groundwater development), but not so much on the 'stock' of the resource. If groundwater resources are recognized as natural capital which generate income flows and sustain biophysical flows of ecosystem services, then the level of the 'stock' is in fact critical in generating such flows in the present and in the future. Finally, from an economic viewpoint, it does not make sense at all to split quality and quantity dimensions. Actual groundwater demand occurs at a specific time and place, and with specific quality attributes.

Environmental outcomes

The range of environmental externalities of groundwater is wide and the extent to which they should be assessed and any needed remedial action taken will depend on capacity to monitor and on the costs and feasibility of assessment and remediation

Environmental outcomes can be broadly interpreted, from maintenance of environmental quality standards in groundwater to the maintenance of low flows or wetlands and their associated biodiversity. Such is the array of environmental externalities associated with groundwater abstraction and pollution, that environmental impact assessments may not catch all of them, or if they attempt to do so (such as in the USA Superfund), the costs of remediation can be infinite (National Research Council, 1997). Capturing all the externalities and assigning a value to benefits foregone may be an exercise that can only be undertaken in specific (well financed) cases. However, the regional experience with the EU Water Framework Directive is also instructive in the regulation of chemicals and practices that cause aquifer degradation, together with reports on the environmental status of the basins in which groundwater circulation may play a key role in maintaining aquatic ecosystems. The key considerations in advancing such broad environmental regulation with respect to groundwater are:

- Capacity to assess and monitor and regulate
- Costs of environmental impact assessment and monitoring
- Costs of remediation

7. Conclusion

7.1 Governance of groundwater exploitation is unavoidable

Despite its importance, understanding of groundwater is limited and this is reflected in decisions and behavior over its exploitation and conservation.

Groundwater is an extremely valuable resource for human society and the environment, but the general public, decision-makers in the water sector and groundwater users mostly have very little notion of groundwater and its economic significance, the many opportunities it offers, its close linkages with surface water and other domains of our physical environment, and the many problems that may arise in absence of good groundwater governance and effective management. This limited awareness is reflected in their decisions and behavior and the failure to act before irreversible damage to groundwater and aquifers has been done. For the most part the act of groundwater exploitation does not throw up management practices, infrastructure and institutions that are governable. At the point where consuming behavior is expressed in an open market (such as the purchase of food) the behavior is generally 'governable' and trading standards, food safety, measures and values become widely applicable. Surface water exploitation tends to reveal such type of things quickly to the extent that it usually requires visible structures and institutional arrangements (water utilities) that are governable. With the exception of municipal well fields with well-organized and marked recharge and/or pollution protection areas, the bulk of groundwater exploitation remains hidden from such public scrutiny.

Groundwater is threatened by depletion and pollution in many locations, and eventually groundwater governance is needed to manage the resource and control or mitigate problems

Groundwater in many parts of the world is under pressure from intensive abstraction, and pollution is an even more widespread threat. Common problems resulting from these threats are overexploitation (excessively declining groundwater levels) and groundwater quality degradation, both of which bring negative impacts for the human society, ecosystems and the environment. Various drivers of change, like demography, economic and technological development and climate change, can aggravate the situation. Under good governance conditions, adequate groundwater resources management measures may prevent, control or mitigate such problems. The implication of paying insufficient attention to groundwater governance is for many groundwater systems around the world that they will sooner or later degrade (by depletion, by pollution or otherwise), often irreversibly. This translates into negative impacts such as a steady reduction of economic benefits obtained from groundwater, water security problems for those depending on groundwater, loss of valuable wet ecosystems and environmental problems (e.g. land subsidence). Therefore, it is time for effective action, facilitated by good groundwater governance.

Groundwater governance has to be adapted to the wide range of physical, socio-economic and political settings

Globally there is large variation in groundwater occurrence, quality, use, opportunities and risks. The way in which humans interact with groundwater depends on the social, economic, cultural and political setting. Consequently, there is no 'one size fits all' model for good groundwater governance — approaches should always be tailored to local conditions.

7,2 Starting points are there

This diagnostic has identified specific gaps in groundwater governance and indicated pathways to close them

This Diagnostic has highlighted the need to make a case for a global commitment to introducing and improving groundwater governance on the basis of a few principles or guidelines for implementation — but above all making the invisible visible. The missing elements outlined in Chapter 4, together with information on success stories and other positive experiences, have indicated a set of pathways toward improved groundwater governance detailed in Chapter 6.

Following these pathways can help put in place more practical governance arrangements…

The regional contrasts and policy priorities will be significant, but overall this synthesis of groundwater perspectives on governance argues for a smarter, implementable approach to groundwater use and aquifer protection to sustain a set of critical aquifer services.

… that facilitate aquifer management in pursuit of societal goals – even if simple sustainability is not achievable

A general notion of 'sustainability' in terms of simple recharge and withdrawal budgets is not sufficient. Rather, a more informed appreciation of how governance arrangements can be used to manage aquifers in pursuit of agreed societal goals is called for. Many solutions to conserve aquifer services in the long term may have sound technical and economic rationale but may not be politically viable.

Governance arrangements to maintain aquifer quality may prove more challenging than just managing quantity

The distinction between the governance of direct groundwater use and the governance of polluting behavior that impacts the quality of groundwater in aquifers is important.
Two, sometimes mutually exclusive, sets of actors are implicated and in many ways improving the governance of behavior to maintain or improve groundwater quality may be more problematic than improving the governance of direct groundwater use.

Good groundwater governance has to recognize that users are the key to good management, and measures have to recognize users' priorities and align incentives for change with these priorities

Positive solutions — where they can be identified — have derived from direct engagement with groundwater users. This tends to confirm the overall observation that 'good' groundwater governance is likely to commence with 'socialization' of users in ways that reveal their common interest in a particular aquifer. These interests may have nothing to do with long-term sustainability as such, but are more likely to be linked with health and livelihood concerns. Will our children be less ill in the future, will we be able to rely on this aquifer next year?

Those whose livelihoods directly depend upon access to groundwater are making many complex but private decisions over their use of the resource and the technology to abstract it. Hydrogeology is also complex. For these reasons, management measures have to give users incentives to change if they are to be encouraged, for example, to realign their behavior towards common good goals of sustainability or equity.

These approaches to collective governance arrangements are typically easier to implement in rural areas than in and around towns

There are more examples of experimentation with governance of groundwater in rural settings where agricultural use dominates and incentives to get aquifer management 'right' are high. Evidence from peri-urban and urban groundwater users in effecting collective approaches to aquifer are very few, even if the intensity of groundwater abstraction and dependency is more concentrated. This may be partly because the mix of stakeholders and institutions is likely to be more complex and their perspectives and aspirations more varied than in rural areas.

Some groundwater opportunities have been foreclosed through neglect but responsible, conjunctive management in line with socio-economic and political realities could open up new opportunities

The Thematic Papers prepared within the Groundwater Governance Project set the basis for investment in institutional arrangements to modify human behavior in relation to aquifer use. Together with the Regional Consultations, they serve as a basis for the Global Diagnostic, Vision and Framework for Action which are intended to provide a vision and guidelines to implementation of that vision. The need for improved groundwater governance to meet expanding human demands is emphasized but it is also accepted that groundwater opportunities have already been foreclosed through neglect. Other groundwater development may expand if we can learn to manage groundwater responsibly — in conjunction with surface water management and in tune with the political realities that overlie aquifers. Governance arrangements are fundamental in building this flexibility.

Governance principles and recommended approaches to applying them can guide management at the local level — and the overall governance framework can then be adjusted in the light of this 'bottom up' reality

There are no hard do's or don't in promoting groundwater governance – each governance framework needs to be adapted to the local realities. The application of the enhanced governance principles described in Chapter 6 will help — equitable access; sustainability;

transparency; participation; accountability; integration within water policy; the 'precautionary principle'; and knowledge. Four key recommendations on how to apply these principles in practice emerge from this Diagnostic:

- **Emphasize simplicity and the communication of action-oriented messages.** Groundwater theory may be complex, but effective practice has to be simple and straightforward if it is to be adopted at scales that will make a difference. Can more be done to first arrive at scientifically robust groundwater assessments and then get the essential technical messages across before it is too late? What are the measures that can actually be applied, and how can incentives be aligned to encourage stakeholders to buy in to them?

- **Recognize that actual management is done by and with stakeholders on the ground — and work back to adjust the overall governance framework accordingly.** The overall institutional environment, including national legal frameworks for water management may or may not be well-designed, but the local institutional arrangements — with local stakeholders involvement — that are likely to really determine outcomes. Before adjusting the former, has enough been understood about the latter?

- **Account for the benefits and costs of groundwater development, and use the results to convince decision-takers of the need for reform.** If groundwater itself is 'invisible', then the groundwater economy is likely to be even more so. A clear account of how groundwater quantity and quality allow a national economy to function is a fundamental requirement in making a case for groundwater governance. Equally important is an account of the social and environmental impacts of development — the externalities associated with groundwater drawdown and pollution.

- **Good groundwater managers need to be innovative technically — but also equally proactive in seeking partnerships with key stakeholders — farmers, industry, municipalities etc. — and in investing in strong organizational capacity.** The managers of groundwater could do more to innovate in the use of groundwater storage and aquifer services — from conjunctive use to maintain municipal water supplies to the safe use of natural remediation properties in aquifers. However, they also need to be equally innovative in collaborating with public and private institutions to obtain more leverage for groundwater governance. Industry, agriculture, municipalities and major manufacturing sectors can be guilty of aquifer depletion and degradation — but they can be key in reducing stresses. This should be a strong incentive for groundwater managers and policy makers to be more pro-active in their engagement with national integrated water resource management and with the preparation of forward looking investments related to strengthened groundwater governance.

7.3 Concluding remarks

Given the global scope and range of the studies, the results of this Diagnostic offers a basis for improving groundwater governance

The global diagnostic presented is based on information, interpretations and opinions of hundreds of groundwater professionals from both the public and private sectors representing different regions from around the world. Together, they produced a kaleidoscopic picture of groundwater governance, more comprehensive than ever before assembled. Nevertheless, the picture that emerges is representative of contemporary circumstance with the proviso that assessments presented for specific countries or aquifers should not be interpreted as applicable everywhere and at all scales.

*The Diagnostic **has** been able to demonstrate that almost everywhere governance arrangements have not caught up with the pace of groundwater exploitation and changes in aquifer state*

The information is considered robust enough to conclude that the current state of groundwater governance almost everywhere is still far from an assumed 'ideal state' of groundwater governance characterized by groundwater being managed "through the application of responsibility, participation, information availability, transparency, custom and rule of law"[11].

The greatest shortcoming of groundwater governance has been its failure to grasp the central importance of the human dimension — human goals, incentives, rights, practices and constraints — and the consequent neglect of stakeholders in governance and management

The disappointing results of groundwater resources **management** measures, particularly non-technical measures intended to change human behavior, can be attributed to gaps or lags in the system of groundwater **governance**. The intention of groundwater resource management measures may be technically informed but lack of communication with local stakeholders leads to their interests being overlooked and to an atmosphere of mutual mistrust between the public administration and local stakeholders. The efforts required to improve understanding, gain stakeholder confidence and produce compliance with monitoring and management

[11] These are the criteria according to the definition of groundwater governance by Saunier and Meganck (2007). One may argue that 'custom' may be deleted from this list since it is included already in 'rule of law'.

measures tend to be greatly underestimated. In short, neglecting the 'human dimension' can cause even the best intentioned management plans to fail during implementation.

The priorities for improving governance are thus: ***stakeholder involvement*** *— awareness, communications, structures for cooperation and collective action;* ***knowledge generation and sharing****;* ***capable managing agencies****;* ***integrated water resource management approaches****; and* ***inter-sectoral cooperation and public-private partnerships***

Among the general priority areas for improvement of groundwater governance is first and foremost **stakeholder involvement**: awareness raising at all levels and developing modalities for effective communication and cooperation amongst relevant stakeholders (ranging from government agencies to the private sector, local groundwater users and ordinary citizens). Complementary recommendations of major importance are: **knowledge**: paying significantly more attention to monitoring networks, exchanging data and information; **strengthening public agencies** mandated for groundwater management; **integrated water resource management**, including conjunctive management of groundwater and surface water; and developing coordination mechanisms with **interlinked sectors** and forging **public-private cooperation mechanisms**.

These priorities are summarized in the Global Vision and developed into guidelines for action in the GEF Framework for Action — putting all this into practice requires adaptation to local specifics, setting of realistic goals, and mobilizing political support

Given the great importance of groundwater in most parts of the world and the many associated challenges ahead, improving groundwater governance is essential. In the separate *'GEF Framework for Action'* guidelines and recommendations for action will be presented, developed on the basis of this Global Diagnostic and the accompanying Global Vision on Groundwater Governance. Programmes of action for any particular region or area should take area-specific conditions into account, take advantage of locally favorable opportunities (seeking highest cost effectiveness), clearly identify priority areas for action and ensure that realistic goals are set. Mobilizing high-level political support for such programmes will be indispensable.

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