# Part II

# Governance

# Groundwater Governance in Australia, the European Union and the Western USA

6

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**Abstract**

Groundwater governance can be defined as the system of formal and informal rules, rule-making systems and actor networks at all levels of society that are set up to steer societies towards the control, protection and socially acceptable utilization of groundwater resources and aquifer systems. Groundwater resources are very diverse and groundwater governance is complicated by the common pool nature of most groundwater resources, information gaps, and the diversity of stakeholders and their interests. There are few comparative studies of groundwater governance. This chapter contributes to that literature by means of a high level comparison of groundwater governance in Australia, the European Union and the Western USA. The comparison is structured using the five categories of governance issues defined in the Earth System Governance Project; architecture, access and allocation, accountability, adaptiveness, and agency – defined in this case as management organisation. The EU WFD has gone furthest towards an integrated framework to manage groundwater quantity and quality objectives, but there are many implementation challenges. Australia's system of annually adjustable water entitlements and related water markets provides security, efficiency and flexibility but it is not yet clear how successfully environmental water allocations can be integrated within this framework. The system of prior appropriation in the Western US provides clearly defined priorities for water allocation, but lacks flexibility during extreme droughts. Fully integrated groundwater management, as intended by the WFD, is a very ambitious goal. The advantages of a strong central direction and coordination together with decentralised local management could be obtained through

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A.J. Jakeman et al. (eds.), *Integrated Groundwater Management*,
DOI 10.1007/978-3-319-23576-9_6

a decentralised system of collaborative planning and management at sub-basin scales nested within an overarching groundwater planning framework at the jurisdictional or basin scale. This system could take various forms in different countries depending on social preferences and institutional settings and capacity.

## 6.1 Introduction

Groundwater makes up 30 % of the world's freshwater and 99 % of the world's liquid freshwater. Groundwater supplies over 40 % of global irrigation water and 50 % of municipal water withdrawals. Two billion people depend on groundwater for drinking water. The consumption of groundwater is growing rapidly driven by increases in global population and agriculture and overextraction, and pollution of groundwater is increasing in many parts of the world. This is reducing groundwater reserves and harming rivers and lakes that are connected to groundwater (see Chap. 2 for more detail on the scale of the groundwater problem internationally). As groundwater is depleted supply costs increase leading to reduced access for the poor (Wijnen et al. 2012). Therefore good governance, protecting groundwater resources is crucial, for environmental, economic and social reasons.

Several features of groundwater and its use present challenges for its governance. Firstly, groundwater resources are not visible or well understood. The impacts of groundwater use and pollution are often hidden, and only become apparent over tens or even hundreds of years (Moench 2004, 2007; Wijnen et al. 2012). Secondly, groundwater governance has to allow and account for the large diversity of groundwater resources, users and use impacts. Groundwater is also subject to a diverse range of point source and diffuse pollution. Thirdly, groundwater is often subject to unsustainable levels of exploitation and depletion, because it is a common pool resource – individual users cannot exclude others (Ostrom 1990; Ostrom et al. 1994). Fourthly, even when individual groundwater users collaborate, they cannot be expected to manage remote impacts of groundwater pumping on other resources and the environment. Because of these features groundwater governance is a complex process that requires coordination across multiple spatial and time scales, sectors and administrative levels. Partnerships between governing authorities and water users are needed to address these problems (Schlager 2007; Blomquist and Schlager 2008).

The definition of groundwater governance in this chapter is adapted from the definitions in the Earth System Governance Project (Biermann et al. 2009) and the global diagnostic on groundwater governance (GEF et al. 2015). Groundwater governance is defined as the system of formal and informal rules, rule-making systems and actor networks at all levels of society that are set up to steer societies towards the control, protection and socially acceptable utilization of groundwater resources and aquifer systems.

There are few comparative studies of groundwater governance. This chapter contributes to that literature by means of a high level comparison of groundwater governance in Australia, the European Union and the Western USA. The comparison is structured using the five categories of governance issues defined in the Earth System Governance Project; architecture, access and allocation, accountability, adaptiveness and agency – defined in this case as management organisation.

The remainder of this chapter proceeds as follows. The next section introduces the importance and special features of groundwater. These features present a number of challenges for groundwater management. The following section discusses the challenges for groundwater governance in terms of the five issues defined in the Earth System Governance Project. The main part of the chapter includes a comparison of groundwater governance in Australia, the EU, and the western United States. This is followed by a summary assessment of the strengths and weaknesses of groundwater governance in the three regions and some governance difficulties and dilemmas.

## 6.2 Framework for the Assessment of Groundwater Governance

Groundwater governance involves collective action to ensure socially-sustainable utilisation and effective protection of groundwater resources for the benefit of people and groundwater dependent ecosystems (Foster et al. 2009). Groundwater governance as defined in this project refers to forms of steering societies that go beyond government policy-making and include a wide variety of decision-making structures and processes at all levels of society. These involve a wide variety of non-state actors representing industries, scientists, environmental interests and other parties interested in groundwater (Foster and Garduno 2013). In the remainder of this chapter groundwater governance is analysed using a framework based on the five issues defined in the Earth Systems Governance Project (Biermann et al. 2009).

The Earth Systems governance framework enables a large number of governance issues to be grouped into five major classes: architecture, access and use, accountability adaptation and agency and some links between the five issue classes are also established within the framework. Further details of this classification applied to groundwater are given in Table 6.1 and in the remainder of this section.

**Table 6.1** Classification of earth system governance issues

| | |
|---|---|
| **Architecture** | Central principles, policies and institutions that guide sustainable groundwater use and protect groundwater quality, and interactions between them |
| **Access and use** | Institutions and procedures that determine who has access to groundwater, for what purposes and how groundwater is allocated |
| **Accountability** | Institutions and procedures that provide accountability for groundwater protection and use |
| **Adaptation** | How groundwater users, governments and third parties respond and adapt to changes and uncertainty in groundwater availability, use and governance |
| **Agency** | Private and public sector responsibilities for groundwater management |

The classification aligns with major themes of governance research and the framework has been subject to extensive peer review and has now been in use for several years.

### 6.2.1 Architecture

Groundwater extraction always creates an impact on other resources or the environment somewhere in a hydrological system. Before extracting groundwater a decision is required about the sustainable level of impact that can be accommodated by the system. A sustainable yield can be determined by a combination of two elements. Firstly, stakeholders negotiate a "consensus" or "acceptable" yield that enables them to set management goals. The acceptable yield may be defined in terms of specified resource condition targets. Secondly, scientists and engineers calculate the "operational" yield – the amount of groundwater available through different methods able to meet management goals (Richardson et al. 2011; Pierce et al. 2011). Decisions about acceptable groundwater yield and resource condition targets depend on political judgements about the weights that should be given to consumptive and environmental water consumption now and into the future.

The difficulty of establishing quality standards for groundwater increases with the variability of water quality and use over space and time. Groundwater quality regulation requires definition of well-defined groundwater and environmental quality standards, indicators/measures that enable the achievement of those standards to be assessed, criteria against which the success or failure of specific groundwater protection strategies or interventions can be evaluated (e.g. compliance with environmental quality standards) and evaluation of those interventions (Quevauviller 2008).

### 6.2.2 Access and Allocation

Comprehensive, well defined, secure legal entitlements provide incentives for investment and collective water management (Ostrom 2005; Bruns et al. 2005). A distinction needs to be made between appropriation of groundwater for private use and provision of groundwater for public benefit. Water property rights give individuals an incentive to make the best use of groundwater for their individual purposes, but individuals do not have an incentive to provide groundwater for the environment or to take account of "external" impacts of their use on resources that are remote in space or time.

The collective allocation of entitlements to access and use groundwater is appropriate because of the common property nature of groundwater resources and the external impacts of their use. Collective allocation may be undertaken by elected governments or by other organisations that represent stakeholders, both water users and others. Access and allocation rules can be set out in legal documents such as in water plans, or more informally in local agreements (Tang 1992).

Water allocation describes the process that sets out how, by whom and on what basis decisions are made about access to and use of water (Turner et al. 2004). Water allocation processes take place on different sectoral and administrative scales. Allocation refers to both the allocation of groundwater, and also responsibilities and risks related to groundwater management. Clear allocation principles and priorities are particularly important to deal with water scarcities.

Groundwater allocation can be assessed in terms of its effectiveness, efficiency and fairness. Effectiveness is indicated by whether water allocations are sustainable and meet quality standards. Efficiency is indicated by whether groundwater is allocated or can be transferred to its most economically efficient use. Fairness is indicated by whether people and communities have access to water of acceptable quality to meet their needs. The allocation of groundwater access and use entitlements is complicated by variation in legal authorities across administrative boundaries, conflicts between competing users and uncertainties about future biophysical and social conditions (Blomquist et al. 2004). The agriculture sector is the main user of groundwater in many countries, but many cities depend on groundwater. As agriculture develops and cities grow the access and allocation of groundwater becomes more challenging.

### 6.2.3 Accountability

Two important aspects of accountability can be distinguished. Democratic accountability refers to the institutions and procedures that provide public accountability for groundwater abstraction and groundwater quality standards. Technical accountability refers to processes of monitoring and reporting about groundwater condition and use. Both forms of accountability occur at multiple geographical and administrative scales.

Accountability and legitimacy issues have become increasingly important given the increasing complexity of groundwater management organisations, which include private actors and networks as well as elected governments. When central government agencies govern groundwater they are democratically accountable to the government of the country. However, centralised government agencies may be disconnected from water users and communities, who may perceive government decisions as not being consultative or legitimate (Gross 2011). When groundwater is governed by non-government bodies such as water user groups or watershed partnerships the lines of accountability are less clear. Such bodies may give disproportionate influence to particular groups such as farmers but may also offer opportunities for developing deliberative processes that are genuinely engage citizens (Huitema and Meijerink 2012).

Accountability requires the effective measurement and monitoring of groundwater use. This requires the installation of meters on individual wells and collation of use data by managing bodies – government or non-government. Measurement, monitoring and reporting of groundwater use is complicated by the large number and diffuse nature of groundwater users, and by the fact that many of the impacts of groundwater use only become evident after many years (Moench 2007). In many countries, the data available on both groundwater quantity and quality are poor and not standardised compared to the data available for surface water (Biswas 1999).

### 6.2.4 Adaptation

Adaptation can be encouraged by institutional design or implementation processes. Institutional adaptation allows for learning and change in response to unforeseen situations, such as unexpectedly severe droughts or floods, and changing knowledge and policy (Walters 1986; Pahl-Wostl 2007). Regulatory instruments and long-term plans provide direction and certainty to water users but they can be relatively inflexible in responding to change. Flexibility mechanisms such as adjustable shares of volumetric water entitlements, carryover arrangements, water trading and leasing have been built-in to groundwater regulations and plans in Australia and the Western USA to improve adaptability (Ross 2012).

Adaptation is also encouraged by collaborative groundwater governance processes that allow governments, water users and independent experts to collectively learn, negotiate and co-produce groundwater management arrangements (Emerson et al. 2012). It is not sufficient to get feedback through public seminars and discussions. Ongoing engagement of and effective collaboration between policy makers, scientists and practitioners is required (Letcher and Jakeman 2002).

### 6.2.5 Agency

A large variety of non-government as well as government organisations have been given authority to establish and implement groundwater policies and standards in different jurisdictions. Groundwater governance involves a large number of individuals and agencies exercising a wide range of roles and responsibilities. Groundwater governance has often been criticised as being too fragmented, including too many agencies with unclear roles and responsibilities. However attempts to streamline groundwater governance have proved difficult because of the wide diversity in groundwater resource and user attributes.

Groundwater governance poses a cross scale management dilemma. High-level governments can provide effective control, cross sectoral coordination and accountability, and can act flexibly to solve crises. However, hierarchical management can become very complicated at the river basin or sub-basin scale and may displace stakeholder and community action. Moreover, local governments and water users often understand groundwater resources and their importance to communities and the environment better than central governments (Ross 2012).

Special-purpose organisations, such as catchment management organisations in Australia and water districts in the USA may provide a better match with hydrogeological boundaries, better local coordination, and encourage engagement and innovation (Marshall 2005; Cech 2010). However, local organisations lack knowledge and incentives to manage intertemporal impacts of resource use at a river basin scale (Schlager 2007), and sometimes lack public accountability.

## 6.3 Groundwater Governance in Australia, the European Union and the Western United States

### 6.3.1 The Context for Groundwater Governance

Increasing groundwater use in Australia, the EU and the USA underlines the importance of good groundwater governance. Groundwater provides about 17 % of water used in Australia, and much higher percentages in some regions and/or during dry periods. Groundwater use is increasing rapidly. For example between 1993–1994 and 1996–1997 groundwater use tripled in New South Wales and Victoria, the most populous states in Eastern Australia (the Australian Government 2001). By 2030 average groundwater use in the Murray-Darling Basin – which includes the majority of Australia's irrigated agriculture, is estimated to increase from an average of 14 % to 27 % of the total water used (CSIRO 2008).

Groundwater supplies about 65 % of public water supplies in Europe (Jacques 2004), and 23 % of agricultural water. There are wide variations between the EU states with a much larger proportion of agricultural water coming from groundwater in southern Europe (EASAC 2010). In many rivers across Europe more than 50 % of annual flow is derived from groundwater, and in dry periods this can rise to more than 90 % (European Commission 2008).

In 2000 groundwater provided about 20 % of water consumed in the USA, 37 % of public supply withdrawals and 51 % of drinking water. There is substantial variation between the states, and in the arid Western USA there is substantial water scarcity, groundwater over drafting and related problems including land subsidence, saltwater intrusion and pollution. Groundwater use for irrigation has increased substantially. In 1950 only 23 % of irrigation withdrawals were groundwater, by 2000 groundwater's share had risen to 42 % (Kenney et al. 2009).

### 6.3.2 Key Elements of Groundwater Governance in Australia, the EU and the Western USA

Key elements of governance architecture, allocation and access, accountability, adaptation and agency in Australia, EU and the Western USA are summarised in Table 6.2 and described in the following sections of this chapter.

**Table 6.2** Key elements of groundwater governance in Australia, the EU and the Western USA

| | Australia | EU | Western USA |
|---|---|---|---|
| Architecture | National Water Initiative (NWI)<br>Tradable property rights<br>Water plans<br>Drinking water standards | EU water framework directive (WfD)<br>Groundwater quantity and quality standards<br>River basin management plans | No national strategy<br>Tradable property rights<br>Augmentation/ mitigation plans<br>Drinking water standards |
| Allocation and access | Return overallocated basins to sustainable use | Maintain good groundwater condition (quantity and quality) | Maintain property rights of senior (surface water) users – prior appropriation system |
| Accountability | NWI consultation principle<br>National monitoring of NWI, State monitoring of water plans | WFD consultation principle<br>Reporting on river basin plans | No national accountability except for drinking water standards |
| Adaptation | Variable "share" allocations<br>Water markets | EU/National drought management plans<br>Flexible implementation of WFD | Water "rationing" by means of prior appropriation system<br>Flexible implementation of prior appropriation |
| Agency | Centralised governance | Subsidiarity principle<br>Wide range of national settings | Emphasis on local governance by courts and water users monitored by States |

## 6.4 Governance Architecture: Principles, Policies and Institutions

Australia and the EU have both adopted broad scale (continental) water management strategies with embedded groundwater components. The USA has not adopted a single comprehensive water management strategy and relies on a more decentralised approach using historical water allocation norms and principles – prior appropriation in the case of the Western USA. Groundwater governance in Europe is largely based on regulation, Australia has developed a mixed system of regulation and markets, the USA has a polycentric groundwater governance system with a mixture of instruments.

### 6.4.1 Australia

Groundwater management in Australia has been strongly influenced the trajectory of surface water reform. Principles for water governance in Australia are contained in the 1994 and 2004 Council of Australian Government (COAG) agreements on water reform. The 1994 COAG agreement included full cost recovery, separation of water from land titles, integrated catchment management and the establishment of water markets and trading (COAG 2004). The 2004 Intergovernmental Agreement on a National Water Initiative (NWI), included the establishment of secure water access entitlements, water access planning with provision for environmental and other public benefit outcomes, the return of over allocated systems to sustainable levels of extraction and further development of water markets, best practice water pricing and national water accounting.

Section 23 of the NWI provides for "a nationally consistent market, regulatory and planning based system for managing surface water and groundwater resources", while 23 (x) recognises "the connectivity between surface and groundwater resources and connected systems managed as a single resource". Surface water and groundwater for human consumption and the environment are managed within this framework but water quality is managed separately.

Under Australia's federal system of government, the primary right to own or to control and use water is vested with the States and Territories (Lucy 2008). The States and Territories have enacted "mirror" legislation to incorporate the NWI in state laws and regulations. Groundwater is allocated in accordance with priorities established by the State governments. The 1992 Murray-Darling Basin agreement placed a cap on surface water use (MDBC 2006), and included a formula for allocating water among MDB jurisdictions, but there was no similar cap on groundwater use, which continued to expand for a further decade.

The Australian Government's Water Act 2007 requires that the new Murray-Darling Basin Authority prepare an integrated surface and groundwater plan for the basin. The Basin Plan was passed by the Australian Parliament on 26 November 2012. The plan includes sustainable diversion limits for groundwater resources, but these have been criticised insufficiently recognising surface water groundwater connectivity and for failing to take account of environmental impacts of groundwater pumping (Nelson 2012).

Groundwater quality is not included as a central objective or element in the NWI. Water quality is subject to a separate agreements between Australian governments, including the National Action Plan for Salinity and Water Quality and the National Water Quality Management Strategy (NWQMS). The NWQMS contains detailed standards for water that is to be used for specific human consumptive purposes, which are included in state legislation, but groundwater quality monitoring is generally poor. Groundwater salinity is increasing and groundwater dependent ecosystems are threatened by over-extraction and poor groundwater quality in some areas. Nitrate levels in some irrigated catchments exceed national drinking water standards and ecosystem protection guidelines (Geoscience Australia 2010).

### 6.4.2 The European Union (EU)

The European Water Framework Directive (WFD) developed from a series of earlier water directives which were driven by concerns to ensure clean water supplies and to maintain environmental quality in the EU. The WFD is a legally binding policy that provides a common framework for integrated management of the quality of all types of water in Europe. The WFD came into force in December 2000.

The primary objectives of the WFD are to protect and enhance water quality and aquatic ecosystems and to promote sustainable water use. The WFD includes five key elements; river basin management based on river basin plans, a combined approach to pollution control linking emission limit values to environmental quality standards, definition of "good water status", the principle of full cost recovery for water and increasing public participation in policy making (Page and Kaika 2003). Good water status includes a focus on ecological status for surface water and quantitative status for groundwater i.e. groundwater levels linked to the achievement of ecological objectives (Wijnen et al. 2012).

The WFD is a supranational law which had to be transposed into domestic law of the EU Member States. Parts of the WFD, especially the chemical status of water bodies and the so-called priority substances contain specified standards. Environmental standards have been set for surface water for 33 substances. The ecological goal-setting process allows member states considerable freedom regarding both policy process and policy output, e.g. targets and end goals for water bodies. Implementation is flexible in several important ways including the designation of the relative "modification" of water bodies, the degree of formalisation of goals and environmental standards, scale of implementation, stakeholder participation, integration with other policy fields, and finally exemptions from general targets (Liefferink et al. 2011). If member states fail to transpose the WFD the European commission can initiate an infringement procedure before the European Court of Justice which may impose financial penalties (Mechlem 2012).

The WFD (Article 4.1(b) (i and ii) require member states to implement all measures necessary to prevent or limit the input of pollutants into groundwater, to prevent the deterioration of the status of all bodies of groundwater, and to protect enhanced and restore all bodies of groundwater, ensuring a balance between abstraction and recharge with the aim of achieving good groundwater status within 15 years.

Groundwater provisions of the WFD require member states to define and characterise groundwater bodies (within river basin districts), identify bodies at risk of not meeting WFD objectives, establish registers of areas where groundwater requires protection, establish groundwater threshold values (quality standards), pollution trends, and measures to prevent or limit inputs of pollutants into groundwater. Implementation of these provisions includes establishment of monitoring networks, and inclusion of groundwater protection in river basin management plans and programs of measures for achieving WFD objectives for each river basin district (European Commission 2008).

River basin management plans were due to be submitted to the Commission by 2009 and programs of measures have to be in force by the end of 2013. However, there are large differences between member states in the enforcement of EU standards. More than 50 % of groundwater bodies in some southern European states are at risk of not meeting WFP requirements because of the overpumping and pollution (EASAC 2010).

### 6.4.3 Western USA

There is no overarching national strategic framework for water management in the United States or across the western USA. Water for human use and the environment, and water quantity and water quality objectives are managed separately. Each individual state has "plenary control" over the waters within its boundaries and state of local governments set goals for regulating water use and water pollution.

In the Western USA the doctrine of prior appropriation was developed to set water allocation priorities and to address disputes among landowners. The doctrine includes four key elements; establishment of a water right by diverting water and applying it to a beneficial use, and (once beneficial use was established) the right to exclude others from using the same water, to use the water in allocation distant from the source and to sell the water to third parties (Jones and Cech 2009). Subsequently most western states adopted groundwater legislation that extended the doctrine to cover groundwater (Schlager 2006).

State law underpins the doctrine of prior appropriation (Kenney et al. 2005). If low stream flows prevent senior rights holders from diverting the water to which they are entitled, the seniors put a "call" on the river, requiring all upstream rights holders "junior" to the caller to stop diverting water until adequate streamflow is restored (Howe 2008). In the prior appropriation system most groundwater rights holders are relatively junior and have to make good their impacts on senior rights holders. In times of water scarcity this can result in groundwater pumping being terminated (Jones 2010).

Groundwater drawdowns and pollution have led to the choice between reducing the take of existing users or restricting new development. In some cases groundwater users have successfully lobbied against restrictions leading to the ongoing depletion of resources such as the High Plains aquifer (Sophocleous 2009).

The US Federal government has had a strong involvement in water development and distribution, through major water projects and more recently through federal environmental law (Kenney et al. 2005).

The Federal Clean Water Act (s102) provides for the development of comprehensive programs for preventing, reducing or eliminating the pollution of groundwater used for human consumption. The Act (s106) also allows for funding to support groundwater protection programs but in practice the costs of remediating source water pollution are met by municipal governments and industry (GWPC 2007). Federal pollution control laws including the Resource Conservation and Recovery Act and the Comprehensive Environmental Response Compensation and

Liability Act provide for landowners to be liable for point source pollution including impacts on groundwater (Smith 2004). The Endangered Species Act provides for the conservation of threatened and endangered plants and animals and their Habitats, and is an important driver for environmental water provision.

Application of prior appropriation to groundwater has not prevented groundwater depletion in unconnected basins, while in connected basins it has prevented the use of groundwater when surface water is scarce (Schlager 2006), Groundwater quality controls are largely limited to point source pollution and sources of drinking water, there are no systematic controls on diffuse pollution. Thomas (2009) argues that the US would benefit from the adoption of a federal approach similar to the EU groundwater directive to protect its groundwater resources.

## 6.5 Access and Allocation

### 6.5.1 Australia

Under the NWI Australia has adopted a framework of water entitlements that are completely and transparently defined, separated from land wherever possible, specified in registers, monitored and enforced (NWC 2009). Entitlements to access water, to take water in a particular season/year and to use water at a particular place and time for a specific purpose are separated from land ownership.

Surface water allocations are made to satisfy these entitlements in each season/year as defined in the relevant State water plan and depending on the amount of water available. During scarcities lower priority agricultural uses receive less than the face value of their water entitlement. In most Australian jurisdictions the separation of water entitlements from land promotes the development of water markets and trade in water.

The allocation of shares of total available groundwater is more difficult to clearly define. Groundwater availability is often defined according to proportion of long-term recharge that can be extracted without compromising the integrity of the water source and the ecosystems and communities that depend on it.

The use of groundwater has been restricted in a limited number of management areas on the basis of exploitation of, or stress in surface and/or groundwater resources. In some highly exploited stressed groundwater systems, annual allocations of a share of water entitlements have allowed authorities to control groundwater exploitation without compulsory reduction of entitlements (NWC 2006). Cease to pump rules are applied to some groundwater resources to maintain minimum flows in connected streams. However, there is no systematic national approach.

The efficient allocation of resources has been boosted by the development of water markets but the effectiveness of the protection of groundwater resources is complicated by the overallocation of water use entitlements (Young 2010), and the failure to properly account for impacts on groundwater use of surface water resources (Evans 2007). There are a range of community perceptions about fairness in water allocation, in particular there is some disagreement about the balance of allocations between water for the environment and irrigation (Connell et al. 2007).

### 6.5.2 The EU

In the EU the entitlement to use water is generally given by public authorities through licences and permits. Water allocation is carried out by different authorities and agencies at different levels. Authority to pump groundwater is generally given through permits that refer to the quantity of water abstracted and/or pumping capacity. Permits are issued for varying periods of time in different states. In some states including France, Germany and the UK environmental impacts are considered when granting permits.

National authorities have powers to restrict abstractions during times of water scarcity or drought. Some countries such as Netherlands, Spain and France determine restrictions according to a hierarchy of water users. Priority may also be given to particular sectors, or sometimes within sectors, for example for specific crops (European Commission 2012).

Also the WFD sets a "good quantitative status" for groundwater which implies an obligation to ensure a balance between (natural) recharge and abstraction over a river basin management cycle. However, the implementation of the programme of action that has followed the groundwater directive has concentrated on water quality issues rather than over abstraction.

Regulation of groundwater has not kept pace with the rapid growth in groundwater use in terms of both users and volumes used. Different member states use different combinations of instruments to manage groundwater resources. In some parts of the EU land-use control is the main instrument. For example in the UK environmental agencies have defined source protection zones for some 2000 groundwater sources. In many parts of the EU there are regimes for groundwater protection including the licensing of boreholes. However, in many of the southern European states the number of unlicensed users is growing rapidly (EASAC 2010).

The effectiveness of the Water Framework Directive is being reduced by slow implementation because of the different degrees of ambition and cohesion of the efforts of member states (Liefferink et al. 2011), and technical challenges including information processing (Hering et al. 2010). In southern Europe where the economic and social dependence on groundwater takes precedence over ecological considerations a difficult balance has to be struck between the social benefits of current consumption and the broader social and ecological benefits of conserving water dependent ecosystems (EASAC 2010). European water markets for quality or quantity are not well developed, reflecting a European emphasis on administrative water allocation and regulations on water quality. These institutions may be relatively efficient for European conditions, but there are opportunities for markets that can deliver greater amounts of cleaner water at lower costs (Zetland 2011).

### 6.5.3 The Western USA

In the Western USA groundwater access and allocation has been regulated by the operation of the prior appropriation system. Water access and allocation reflects common-law courts decisions from the late 19th and early twentieth century. Surface water rights are generally senior to groundwater rights.

Prior appropriation has worked differently when applied to aquifers compared to surface waters. It has also applied differently to groundwater resources unconnected to surface water (non-tributary) and connected (tributary) resources (Schlager 2006).

In the case of non-tributary groundwater priority acts to limit the number of well permits issued but does not prevent declining water tables. Reasonable declines in water tables are allowed. It is up to state courts to determine what constitutes a reasonable decline on a case-by-case basis. State governments have not intervened to limit the issue of well permits until aquifer depletion and/or negative impacts on other users have become serious. In the case of tributary groundwater, prior appropriation has been adapted to allow some groundwater pumping while protecting senior surface rights. Groundwater pumpers have been allowed to pump water if they can provide water to augment stream flows to prevent injury to surface water users (or the environment). This system prevents long-term over abstraction of tributary groundwater, but it can discourage efficiency because water is forfeited if it is not used within the statutory time period (Neuman 2010) and it prevents the use of groundwater during droughts when it is most needed (Schlager 2006).

Further modifications of state water allocations based on prior appropriation have been needed to allow for the fact that hydrologic systems do not stop at state boundaries (GWPC 2007) and pumping can harm senior water rights in adjoining states. In order to deal with this problem interstate agreements have been negotiated to address cross-border impacts of water use.

Environmental water allocation is managed separately from water for consumptive use and the fairness of the prior appropriation system can be challenged in the sense that it does not service changing social preferences such as environmental water requirements. Federal environmental laws including the Clean Water Act and the Endangered Species Act provide the main driver for environmental water provision, often through an interstate compact. For example, the South Platte Compact requires that between April 1 and October 15 Colorado must ensure river flows do not fall below 120cfs.[1] Colorado has also committed to making 10,000 acre feet of water available between April and September of each year to assist recovery programs for three endangered birds and one endangered fish (Freeman 2011).

[1] 100 cubic feet per second equals 2.82 cubic metres per second.

## 6.6 Accountability

### 6.6.1 Australia

In Australia there are several levels of democratic accountability for groundwater management. The National Water Commission (NWC) has responsibility for reviewing the implementation of the NWI and reporting to the Australian government. The NWC has published biennial reviews of the NWI. State and Territory water authorities have responsibility for establishing groundwater management plans, and monitoring and enforcing these plans. These authorities report progress to their own government and also to the NWC.

The NWI provides that governments engage water users and other stakeholders in water planning and other reform processes in order to improve certainty and confidence, transparency and information sharing. State water legislation includes provision for consultation in relation to water plans, but consultation often appears more symbolic than real, because it takes place after policy changes have been made and/or does not take sufficient account of stakeholder views (Bowmer 2003). Australian and international experiences show how communities can use collaborative water planning processes to manage cuts to water allocations (Richardson et al. 2011) and for flood and drought risk management (Daniell et al. 2010).

The NWI requires all jurisdictions to ensure adequate measurement, monitoring and reporting systems are in place. The capacity of State and Territory governments to monitor groundwater resources and plans is mixed. Some resources, especially the most highly exploited resources, have relatively good metering and monitoring, but many resources lack basic metering, measurement and monitoring infrastructure. There is a national program to develop this infrastructure. Monitoring of groundwater quality is limited and carried out in an ad hoc manner. There is no consistent national program on groundwater quality monitoring and much of the monitoring has been short term (Geoscience Australia 2010).

### 6.6.2 The EU

Democratic accountability for the implementation of the WFD is complex with local areas reporting to national governments and parliaments who in turn report to the European Community and Parliament. EU member states and the European commission have jointly developed a Common Implementation Strategy (CIS) for supporting the implementation of the WFD. A Strategic Coordination Group (SCG) composed of Member States and stakeholder organisations coordinates cooperation on implementation.

Groundwater planning and allocation systems have high levels of democratic accountability to national governments, and the European Parliament, but sometimes are not perceived as legitimate at local levels because of lack of community participation and deliberative processes. The WFD requires governments to provide information about planned measures and to report on implementation to stakeholders and the general public. It remains a challenge to ensure public access to reliable and consistent information about measures, and to motivate and facilitate public participation (De Stefano et al. 2013).

The SCG has developed guidance documents on groundwater monitoring and groundwater protected areas and is developing guidance on compliance and impacts of land use on groundwater. Measurement, metering and monitoring capability varies substantially among the EU member states, and between regions within the states. EU wide coverage and long-term series of water quality data are not available, and the analysis of water quantity is insufficient in many river basin plans – only 25 % of plans include water availability scenarios and less than 20 % assess data uncertainty.

### 6.6.3 Western USA

State governments are accountable for groundwater management. There is no national accountability mechanism except in the case of transboundary aquifers where there are interstate agreements, and where federal courts or the Supreme Court are responsible for the agreements.

Water management in the US is fragmented, with many overlapping jurisdictions and agencies. Stakeholder engagement, information sharing and accountability is effective across parts of the system but it is very difficult to ensure good communication and consultation across the whole system. Groundwater is governed by a network of water users, water courts and administrative authorities. Groundwater management arrangements are accountable and are perceived as legitimate at a local level, but are not necessarily democratically accountable or perceived as legitimate at a broader level.

There are many gaps in information about groundwater availability and use and there is a need to improve the effectiveness of coordination of groundwater information and data. There is no regular national review or monitoring of groundwater use. The US Geological Service issues periodic reports. The latest covered groundwater use in 2010 (Maupin et al. 2014).

The Clean Water Act (s 106(e)) requires the USEPA to determine that a state is monitoring water quality including groundwater. Thirty states have included some groundwater monitoring in their water monitoring strategies but most of the emphasis is on surface water monitoring.[2] From 1991 the US Geological Survey (USGS) has implemented a National Water Quality Assessment Program that includes groundwater assessments. The USGS has identified 62 regionally extensive aquifers and is carrying out assessments of about one third of them, but most aquifer assessment and monitoring is carried out by the states, and the quality of the programs is highly variable (GWPC 2007).

[2] GWPC-NGWA survey of State groundwater programs, 2006.

### 6.6.4 Monitoring – A Common Challenge

Australia, Europe and the Western USA face similar technical accountability challenges because of shortfalls in groundwater metering and monitoring infrastructure. It is difficult to centrally manage groundwater monitoring because groundwater abstraction is very diffuse. On the other hand groundwater users and local governments often have insufficient mandate or resources to put broadscale monitoring programs in place.

## 6.7 Adaptation

### 6.7.1 Australia

Section 25 (iv) of the NWI provides for adaptive management of surface water and groundwater systems in order to meet productive, environmental and other public benefit outcomes. The National Water Commission undertakes biennial reviews of the implementation of the NWI, but it is left for states to determine how often to review water plans in their jurisdictions. Under the new Murray-Darling Basin plan the Murray-Darling Basin Authority will review state water resource plans, which will usually have a 10 year life cycle.[3]

In the Murray-Darling Basin flexibility is introduced into water allocation in three ways. Firstly water is allocated to entitlement holders on an annual basis depending on water availability. Secondly surface water and groundwater entitlement holders have a limited capacity to carryover water entitlements for later use. Thirdly, surface water and groundwater trading provides some extra flexibility for water users, including the potential to purchase additional water to make up shortfalls in allocations during dry periods, if there is water available for purchase. However, groundwater trading volumes have been relatively small in the Murray-Darling Basin and there has been no recorded surface water and groundwater trading (Ross 2012).

### 6.7.2 The EU

The EU WFD adopts an adaptive water planning approach. National water authorities adopt management plans, including quality standards and programs of measures for water districts for 6-year periods. These plans are monitored and evaluated and the WFD recognises that quality standards and programs of measures may need to be modified in the following 6-year period. However, the legal systems of some member states are not sufficiently flexible to respond to new situations and information.

[3] http://www.mdba.gov.au/draft-basin-plan/delivering-healthy-working-basin/ch03. Accessed 5 April 2013.

The WFD recognises the importance of adaptive mechanisms but they are dealt with through parallel processes including the EU water scarcity and drought policy developments. In 2007 the European Commission released a communication on water scarcity and droughts that laid down a water hierarchy including demand management followed by alternative supply options once the potential for improving water efficiency had been exhausted. This text is, however, not legally binding.

A Commission review of this policy (European Commission 2012) found that while member states have established mechanisms for authorising groundwater use, illegal abstractions remain an important challenge in some parts of Europe. There has been only limited implementation of drought risk management plans, and cost recovery and price incentive mechanisms.

In practice the main flexibility mechanism in the WFD is the degree of freedom given to member states to set groundwater standards and implementation timetables. This approach reflects heterogeneity in the member states, but could result in slow improvements in standards which would reduce the effectiveness of the WFD.

### 6.7.3 Western USA

The prior appropriation system deals with uncertain water supply and shortages by setting clear priorities for allocation of scarce water based on seniority. Junior water entitlement holders must relinquish water in times of shortage. This system provides certainty in the face of changing water supplies but is not very flexible in responding to changing social preferences for the use of water such as demand for new urban development, provision for in stream flows or conjunctive water management. In addition conflicts are resolved by litigation which can be slow and not very responsive to unanticipated crises needing urgent responses.

Adaptive management is gaining a foothold in some agencies like the National Marine Fisheries Service and the U.S. Forest Service, but state water management agencies have a restricted role and responsibilities, to manage the allocation of water for consumptive use or to control water to ensure consumptive supplies. Water quality and water for the environment are managed separately. Because of these management settings water management agencies are not at the forefront of strategic adaptive management (Neuman 2010), although they do provide some leadership in information collection, monitoring and the development of local water allocation plans (Wolfe 2008).

In practice the law of prior appropriation has included provisions for reducing allocations of water to users in response to risks including water scarcity, wasteful or non-beneficial use or displacement by “public rights”. On the other hand junior entitlement holders including municipalities and groundwater groups have obtained enough political power to secure continued allocations (Tarlock 2001). For example, local water plans in Colorado have enabled flexible implementation of the prior appropriation system, without requiring junior groundwater entitlement holders to cease production, except in the most extreme drought conditions (Blomquist et al. 2004).

Water trading and leasing provide further flexibility mechanisms. In Colorado there is a significant amount of water trading, mainly transfers from agricultural to municipal users (Howe and Goemans 2003). Water leasing has enabled farmers to lease part of their water portfolio to municipalities and to reduce their acreage temporarily through crop rotation or fallowing (Pritchett et al. 2008).

## 6.8 Agency

### 6.8.1 Australia

Historically, surface water and groundwater planning, rule development and administration have been separated in Australian jurisdictions. The historical separation of surface water and groundwater science (hydrology and hydrogeology) has reinforced the administrative separation. These separations have hindered the development of integrated water management. Water management and allocation in the Australian states is highly centralised in the hands of responsible ministers and their departments. Surface water and groundwater policy and planning are coordinated at the highest levels of decision-making, but often separate at lower levels.

Government representatives generally consider that policy and implementation functions are integrated effectively. But some water users consider that state water managers do not provide enough information and that some functions are poorly integrated. For example, in the Namoi region in New South Wales, users cited as examples of poor integration the separation of management of overland flows, stock and domestic bores, and issues related to water in the mining sector from other water planning and allocation processes. Local and regional bodies could play a more effective role in water planning and management if there were increased delegation of responsibility to these bodies, increased funding or fund raising capacity and support from high level leadership.

### 6.8.2 The EU

The EU Water Framework Directive initiated the move from national and local water management towards river basin planning, but generally EU member states adapted existing management and administrative bodies to implement the WFD maintaining long-standing water management institutions.

Groundwater governance in Europe is generally coordinated by national authorities, sometimes concentrated at the level of member states and sometimes decentralised to regional and local levels. There is a large diversity of management organisations. Many small states such as Denmark have a relatively top-down approach, whereas the large states exhibit a greater diversity of multilevel governance agencies. In Denmark the Minister for Environment is responsible for river basin management plans, whereas in the Netherlands the competent authority is the Minister for Transport, Water Management and Public Works. In the Netherlands regional water authorities and water boards have a strong role in implementing the WFD.

River basin authorities have a leading role in a small number of member states. France had already adopted a river basin approach before the WFD was conceived and adapted the existing structure of the river basin and sub-basin plans to implement the WFD (Liefferink et al. 2011). Water user groups play an important role in a limited number of countries including Spain. European countries will benefit from continued experiments with groundwater governance and representation from different levels of government, water users and experts.

### 6.8.3 Western USA

Federal water-related agencies and programs are fragmented and require better coordination. More than 30 federal agencies, boards, and commissions in the United States have water-related programs and responsibilities (Christian Smith et al. 2012). The allocation and distribution of water is subject to regulation by state water resource agencies, and is ultimately in the hands of thousands of farmers, hundreds of irrigation districts and a large number of municipalities and industries.

Local groundwater supply and distribution is managed by regional and local water entities, such as mutual water user companies and cooperatives, irrigation districts, conservancy and conservation districts. These organisations provide a crucial link between state laws and policies and individual water users. In some states water districts play an important role in encouraging regional coordination and innovation. In most cases organisation members democratically establish policy and elect management Boards. The organisations are non profit and raise revenue by assessments on shares (mutual companies), on acreage allotments (irrigation districts), or taxes on land or water sharing assessments (conservancy districts) (Freeman 2000). Municipal users and irrigators initiated the South Platte Water Related Activities Program to ensure that instream flow and endangered species obligations are met (Freeman 2011).

Decentralised groundwater management in the Western USA has encouraged many institutional innovations but management effectiveness could be could be improved by strategic watershed planning that integrated consumptive and environmental requirements, and gave governments and water users an opportunity to adjust the prior appropriation doctrine in order to achieve improved water management outcomes.

### 6.8.4 The Influence of Vested Interests

In all three regions historically powerful water authorities and water users exert substantial influence and sometimes resist change. The protection of groundwater dependent ecosystems is an ongoing challenge. Strong leadership and broad community engagement are needed to progress reforms in groundwater management.

## 6.9 Comparative Assessment of Groundwater Governance in Australia, the EU and the Western USA

Drawing on the analysis in the previous section the main strengths and weaknesses in groundwater governance in Australia and the EU and the Western USA are summarised in Table 6.3.

**Table 6.3** Strengths (+) and weaknesses (–) of groundwater (GW) governance in Australia, the EU and the Western USA

| | | Australia | EU | Western USA |
|---|---|---|---|---|
| Architecture | + | NWI provides for comprehensive GW governance | WFD provides comprehensive GW protection | Prior appropriation system safeguards senior water rights |
| | – | Weak GW quality regulation (except for drinking water) | Variable implementation of GW standards | Weak GW quality regulation (except for drinking water) |
| Access and allocation | + | Water plans set sustainable GW use limits | GW allocation included in river basin plans | Effective rationing of scarce water |
| | – | Overallocation of GW use entitlements | Variable implementation of basin plans | GW overuse in some areas |
| Accountability | + | Democratic legitimacy | Democratic legitimacy | Local legitimacy |
| | – | Use monitoring variable, quality monitoring poor | Variable monitoring and reporting | Accountability for impacts at large scales, variable monitoring |
| Adaptation | + | Variable annual water allocation | Flexible implementation of EU standards | Local innovation, flexible enforcement of prior appropriation |
| | – | Centralised system can discourage local innovation | Slow implementation of drought management plans | Rigidity of prior appropriation during droughts |
| Agency | + | Central coordination and planning | Central coordination and planning | Local empowerment and innovation |
| | – | Local delegation and implementation | Local delegation (in most countries) | Strategic planning |

The EU WFD has gone furthest towards an integrated framework to manage groundwater quantity and quality objectives and human and environmental uses of groundwater. The discretion for member states to set their own standards and implementation timetable provides flexibility but also threatens to undermine effectiveness of the WFD. Australia's comprehensive system of water entitlements and related water markets together with annual adjustment of entitlement shares provides security and flexibility for consumptive users and encourages efficient water allocation. But it is not yet clear how successfully environmental water allocations can be integrated within this framework. The system of prior appropriation in the Western US provides clearly defined priorities for water allocation, but lacks flexibility during extreme droughts. Neither the Australian nor the US systems effectively protect groundwater quality or groundwater dependent ecosystems.

Australia, the EU and the Western USA face common groundwater governance challenges. Firstly, the effectiveness of policy and plan implementation varies substantially within the regions. Secondly, there are substantial knowledge gaps, measurement and monitoring is expensive and is highly variable. Thirdly, powerful stakeholders conspire to prevent change when it threatens their interests.

## 6.10 Some Groundwater Governance Difficulties and Dilemmas

Experience with groundwater governance in the EU, Australia and the Western USA raises some unresolved dilemmas relating to relationships between aspects of groundwater governance.

**Is a Comprehensive Integrated Groundwater Governance Architecture Feasible or Desirable?**

A comprehensive system of groundwater governance would integrate the management of groundwater quantity and quality for consumptive and environmental purposes. Only the EU WFD attempts to integrate all four elements. This has proved to be an ambitious goal, and in practice full integration has not been achieved. In Australia the management of groundwater quantity and quality is carried out by separate institutions and in the Western USA all four elements are separated, with variable degrees of coordination in different regions. Degrees of separation of the four elements may be acceptable providing that there are effective coordination mechanisms, which raises the question of what those mechanisms would be.

**What Coordination Arrangements Are Appropriate for Groundwater Governance?**

Groundwater governance involves some particular coordination challenges. Firstly, groundwater resources and user groups are very diverse. Different management rules are appropriate for different resources and users. For example different rules will be appropriate for a shallow alluvial aquifer highly connected to a river compared with a fractured rock aquifer remotely connected with surface water. Secondly, the boundaries of groundwater resources, their flows and their interactions with surface water and the environment are often not well understood. Hence centralised groundwater governance can be very complicated, and groundwater governance is typically organised at multiple geographical, sectoral and jurisdictional scales. A multilevel groundwater governance model including elements of central control and accountability, together with decentralised, participative local agencies is discussed below.

Thirdly, long-term coordination raises special difficulties. The impacts of groundwater use on other resources and the environment can be delayed by many years, decades or even centuries. When long-term impacts are discounted using a "market" discount rate long term impacts have a negligible value. This implies that long-term impacts of groundwater overuse will be considered relatively unimportant compared to short-term impacts, and the maintenance of long-term stocks of groundwater will be considered less important than preserving jobs and environmental icon sites. If discount rates were chosen by means of a deliberative process involving commercial developers, community representatives and user groups as well as governments chosen rate could be lower (or higher) than the average market rate. Community discounting is not the current practice and could be expensive but it could better reflect community views and aspirations for the future (Ross 2012).

**How Can Central Control and Stability Be Balanced with Adaptiveness?**
Well defined, secure entitlements and rules about the use of groundwater increase confidence in and support for groundwater management. At the same time mechanisms that allow the flexible use, storage and exchange of groundwater over time are required to optimise groundwater use in response to changes in climatic and market conditions and new knowledge. There are some working examples of arrangements that combine security and flexibility. The allocation of tradable water entitlements coupled with annual calculation of water available to be used by water entitlement holders has proved to be an effective means of responding to drought in Australia, but requires the prior issue of individual tradable water entitlements – without overallocation. The wide variety of innovations introduced by water districts and communities in the Western United States show the potential for decentralised collaborative groundwater management, although these institutions may lack broad democratic accountability.

**How Can Central Direction Setting and Coordination Be Balanced with Local Agency and Responsibility for Groundwater Governance?**
In practice groundwater governance is typically polycentric, involving a network of governments and their agencies, and special purpose organisations. Participation by groundwater users in decision making is necessary to ensure that users understand each other and have the opportunity to craft mutually acceptable management arrangements taking account of relevant information and uncertainties (Emerson et al. 2012; Ross 2012). This can be achieved by a multilevel approach including both jurisdictional and/or basin wide overviews of water resources and uses and

detailed management arrangements for individual resources. This multilevel approach can avoid the difficulties involved in drafting and communicating a fully detailed management plan at the river basin or jurisdictional scale, but at the same time ensure a coordinated approach to water management consistent with broader social and policy goals. Higher level governments will need to overcome their reluctance to give control to decentralized organisations (Marshall 2005; Ross 2008).

## 6.11 Conclusions

In this chapter groundwater governance in the EU, Australia and the Western USA has been compared using an analytical framework drawn from the Earth System Governance Project. While the high-level international comparison yields some interesting results, the analysis masks many regional and local variations in the study regions.

The EU WFD has gone furthest towards an integrated framework to manage groundwater quantity and quality objectives, but there are many implementation challenges. Australia's system of water entitlements and water markets coupled with variable annual water allocations provides security and flexibility for consumptive users. But neither it nor the US system protect GDEs or prevent diffuse pollution of groundwater. While the US system provides clearly defined priorities for water allocation, it lacks flexibility during extreme droughts.

Fully integrated management of all sources of water, as intended by the WFD, is a very ambitious goal. The advantages of a strong central direction and coordination together with decentralised local management might be obtained through collaborative planning and management at sub-basin scales nested within an overarching groundwater planning framework at the jurisdictional or basin scale. This system could take various forms in different countries depending on social preferences and institutional settings and capacity.



## References

Australian Government (2001) Australian water resources assessment 2000. National Land and Water Resources Audit, AGPS, Canberra

Biermann F et al (2009) People, places and the planet: science and implementation plan of the earth system governance project. IHDP, Bonn
Biswas A (1999) Water crisis: current perceptions and future realities. In: Salman M, Salman A (eds) Groundwater-legal and policy perspectives, vol 456, World bank technical paper number. The World Bank, Washington, DC
Blomquist W, Schlager E (2008) Embracing watershed politics. University of Colorado Press, Boulder
Blomquist W, Schlager E, Heikkila T (2004) Common waters diverging streams. Resources for the Future, Washington, DC
Bowmer K (2003) Look after the land and the rivers: reflections on water sharing. Keynote paper 28th international hydrology and water resources symposium. The Institution of Engineers, Wollongong
Bruns B, Ringler C, Meinzem-Dick R (eds) (2005) Water rights reform: lessons for institutional design. International Food Policy Research Institute, Washington, DC
Cech T (2010) Written statement of Tom Cech, Executive director of the Central Colorado Water Conservancy District concerning managing water for the future: how federal, state and local entities are supporting agriculture. In: Sub-Committees of water and power of the house Committee on natural resources, US House of Representatives, Greeley, 17 May 2010
Connell D, Robins L, Dovers S (2007) Delivering the national water initiative: institutional roles, responsibilities and capacities. In: Hussey K, Dovers S (eds) Water for Australia: the social and institutional challenges. CSIRO, Canberra
Council of Australian Governments (2004) Intergovernmental agreement on the national water initiative. Council of Australian Governments, Canberra
CSIRO (2008) Water availability in the Murray-Darling Basin: a report from CSIRO to the Australian Government. CSIRO, Canberra
Daniell K et al (2010) Co-engineering participatory water management processes: insights from Australia and Bulgaria. Ecol Soc 15(4): Art 11
De Stefano L et al (2013) Easier said than done? The establishment of baseline groundwater conditions for the implementation of the water framework directive in Spain. Water Res Manage 27(7):2691–2707
Emerson K et al (2012) An integrated framework for collaborative governance. Public Adm Res Theory 22(1):1–29
European Academy’s Science Advisory Council (2010) Groundwater in the southern member states of the European Union, and an assessment of current knowledge and future prospects, German National Academy of Sciences. EASAC Secretariat, Halle
European Commission (2008) Groundwater protection in Europe: the new groundwater directive – consolidating the EU regulatory framework. European Commission, Luxembourg
European Commission (2012) Communication from the Commission to the European Parliament, the Council the European Economic and Social Committee and the Committee of the Regions: report on the review of the European water scarcity and droughts policy. COM (2012) 672, Brussels
Evans R (2007) The impact of groundwater use on Australia’s rivers. Land and Water Australia, Canberra
Foster S, Garduno H (2013) Groundwater-resource governance: are governments and stakeholders responding to the challenge. Hydrogeol J 21:317–320
Foster S et al (2009) Groundwater governance: conceptual framework for assessment of provisions and needs, GW-MATE strategic overview series 1. World Bank, Washington, DC
Freeman D (2000) Wicked water problems: sociology and local water organisations in addressing water resource policy. J Am Water Resour Assoc 36(3):483–491
Freeman D (2011) Implementing the Endangered Species Act in the Platte Basin water commons. University Press of Colorado, Boulder
GEF, World Bank, UNESCO-IHP, FAO, IAH (2015) Global diagnostic on groundwater governance. http://www.fao.org/fileadmin/user_upload/groundwatergovernance/docs/general/GWG_VISION.pdf. Accessed 10 June 2015

Geoscience Australia (2010) Assessing the need to revise the guidelines for groundwater protection in Australia: a review report. Geoscience Australia, Canberra

Gross C (2011) Why justice is important. In: Connell D, Quentin Grafton R (eds) Basin futures. ANU Press, Canberra

Ground Water Protection Council (2007) Groundwater report to the nation: a call to action. Ground Water Protection Council, Oklahoma City

Hering D et al (2010) The European water framework directive at the age of 10: a critical review of the achievements with recommendations for the future. Sci Total Environ 408(19):4007–4019

Howe C (2008) Water law and economics: an assessment of river calls and the South Platte well shut down. Univ Denver Water Law Rev 12:181–196

Howe C, Goemans C (2003) Water transfers and the impacts: lessons from three Colorado water markets. J Am Water Resour Assoc 39(5):1055–1065

Huitema D, Meijerink S (2012) The politics of river basin organisations: coalitions, institutional design choices and consequences. In: Lund conference on earth system governance, 18–20 Apr 2012, Lund

Jacques P (2004) Introduction: Western Europe. In: Brentwood M, Robar S (eds) Managing common pool groundwater resources: an international perspective. Praeger, Westport

Jones A (2010) South Platte Well Crisis, 2002–2010. In the water report. Envirotech Publications, Eugene

Jones PA, Cech T (2009) Colorado water law for non-lawyers. University Press of Colorado, Boulder

Kenney D et al (eds) (2005) In search of sustainable water management: international lessons for the American west and beyond. Edward Elgar, Cheltenham

Kenney J et al (2009) Estimated use of water in the United States in 2005, circular 1344. US Department of the Interior, US Geological Survey, Washington, DC

Letcher RA, Jakeman AJ (2002) Experiences in an integrated assessment of water allocation issues in the Namoi river catchment, Australia. In: Rizzoli A, Jakeman A (eds) Proceedings of the 1st biennial meeting of the International Environmental Modelling and Software Society (iEMSs), Lugano

Liefferink D et al (2011) The EU water framework directive: a multi-dimensional analysis of implementation and domestic impact. Land Use Policy 28:712–722

Lucy J (2008) Water regulation: the laws of Australia. Thomson Reuters Australia Ltd, Sydney

Marshall G (2005) Economics for collaborative environment management: renegotiating the commons. Earthscan, London

Maupin MA et al (2014) Estimated use of water in the United States in 2010: U.S. Geological Survey Circular 1405, 56 p

Mechlem K (2012) Groundwater governance: a global framework for action: thematic paper 6: legal and institutional frameworks. FAO, Rome

Moench M (2004) Groundwater: the challenge of monitoring and management. In: Gleick P (ed) The world's water; the Biennial report on the world's water resources 2004–05. Island Press, Washington

Moench M (2007) When the well runs dry but livelihood continues: adaptive responses to groundwater depletion and strategies for mitigating the associated impacts. In: Giodarno M, Villholth K (eds) Agricultural groundwater revolution opportunities and threats to development. CABI International, Colombo

Murray Darling Basin Commission (2006) Murray Darling Basin agreement. Murray Darling Basin Commission, Canberra

National Water Commission (2006) 2005 National competition policy assessment of water reform progress. National Water Commission, Canberra

National Water Commission (2009) Australian water reform 2009: second biennial assessment of progress in implementation of the national water initiative. National Water Commission, Canberra

Nelson R (2012) Submission to house of representatives standing committee on regional Australia's inquiry on certain matters relating to the proposed Murray Darling Basin plan: groundwater SDLs. Parliament of Australia, Canberra

Neuman J (2010) Are we there yet? Weary travellers on the long road to water policy reform. Nat Resour J 50:139–166

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge

Ostrom E (2005) Understanding institutional diversity. Princeton University Press, Princeton

Ostrom E, Gardner R, Walker J (1994) Rules, games and common-pool resources. The University of Michigan Press, Ann Arbor

Page B, Kaika M (2003) The EU water framework directive: part 2 policy innovation and the shifting choreography of governance. Eur Environ 13:328–343

Pahl-Wostl C (2007) Requirements for adaptive water management. In: Pahl-Wostl C, Kabat P, Moltgen J (eds) Adaptive and integrated water management: coping with complexity and uncertainty. Springer, Berlin

Pierce S et al (2011) Aquifer-yield continuum as a guide and typology for science-based groundwater management. Hydrogeol J 21:331–340

Pritchett J, Thorvaldson J, Frasier M (2008) Water as a crop: limited irrigation and water leasing in Colorado. Rev Agric Econ 30(3):435–444

Quevauviller P (2008) Groundwater science and policy: an international overview. The Royal Society of Chemistry, Cambridge

Richardson S et al (2011) Connecting science and engagement, and setting groundwater extraction limits using a stakeholder led decision-making process. In: Connell D, Quentin Grafton R (eds) Basin futures. ANU Press, Canberra

Ross A (2008) Australia. In: Jordan A, Lenschow A (eds) Innovation in environment policy: integrating the environment for sustainability. Edward Elgar, Cheltenham

Ross A (2012) Water connecting people adapting: integrated surface water and groundwater management in the Murray-Darling Basin, Colorado and Idaho. Australian National University, Canberra

Schlager E (2006) Challenges of governing groundwater in US western states. Hydrogeol J 14:350–360

Schlager E (2007) Community management of groundwater. In: Giordano M, Villholth K (eds) The agricultural groundwater revolution: opportunities and threats to development. CABI Publishing, Wallingford

Smith Z (2004) Groundwater: the US experience. In: Brentwood M, Robar S (eds) Managing common pool groundwater resources: an international perspective. Praeger, Westport

Sophocleous M (2009) Review: groundwater management practices, challenges, and innovations in the High Plains aquifer USA-lessons and recommended actions. Hydrogeol J 18:559–575

Tang SY (1992) Institutions and collective action: self-governance in irrigation. ICS Press, Lanham

Tarlock AD (2001) The future of prior appropriation in the new west. Nat Res Law J 41(4):761–793

Thomas R (2009) The European directive on the protection of groundwater: a model for the United States. Pace J Environ Law 26:260–287

Turner K et al (2004) Economic evaluation of water resources in agriculture: from the sectoral to a functional perspective on natural resources management. FAO, Rome

Walters C (1986) Adaptive management of renewable resources. Macmillan, New York

Wijnen M et al (2012) Managing the invisible: understanding and improving groundwater governance. World Bank, Washington, DC

Wolfe D (2008) The future of water administration in Colorado. CBA-CLE, Denver

Young M (2010) Environmental effectiveness and economic efficiency of water use in agriculture: the experience of and lessons from the Australian water reform programme. OECD, Paris

Zetland D (2011) Water markets in Europe. Water Resour Impact 13(5):15–18

# Groundwater Law

7

Rebecca Nelson and Philippe Quevauviller

**Abstract**

This chapter reviews fundamental legal principles relating to groundwater quantity and quality in the United States, Australia and the European Union. It also examines legal approaches to three key "integration" challenges in groundwater law, which arise in relation to many of these foundational principles. First, groundwater law must deal with the relationship between groundwater and surface water—specifically, how abstraction of one should be controlled due to impacts on the other. A second and related challenge is making legal provision for integrating groundwater with its environment, that is, making legal provision for ecological water requirements. Finally, legal frameworks face the significant challenge of dealing with groundwater management in the cross-boundary context. By comparing and contrasting approaches to common and burgeoning legal challenges across different regions, this chapter seeks to highlight the key issues that regulators and groundwater users must consider and confront in dealing with them, and a range of potential legal solutions.

## 7.1 Introduction

Despite their many differences, Australia, the western US and Europe, and indeed major regions of the world, all rely on groundwater as an important water source for cities, agriculture, and ecosystems (Chap. 2). Their systems of groundwater law—a powerful tool for controlling access to groundwater, groundwater depletion, and

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A.J. Jakeman et al. (eds.), *Integrated Groundwater Management*,
DOI 10.1007/978-3-319-23576-9_7

pollution—have proven to be useful for each other to consider, as well as for other nations worldwide (e.g. Garry 2007; Grafton et al. 2009; Thomas 2009; Folger 2010; Ross and Martinez-Santos 2010; Nelson 2011a). This chapter describes key aspects of the groundwater law systems of these three regions and the ways in which they deal with key emerging challenges, both as a guide and a caution to areas facing similar issues. In most countries, groundwater regulation has typically proceeded in "laissez faire mode" (Kemper 2007). But as varying combinations of population growth and its associated industry and agriculture, climate variability, and water quality challenges threaten groundwater in many places of the world (e.g. Bates et al. 2008), the importance of legal tools for dealing with these issues increasingly will come to the fore.

This chapter is structured in three parts. Part One deals with the fundamental legal nature of groundwater, and ownership of groundwater. Part Two describes key differences in the levels of government responsible for regulating groundwater quantity, and introduces key approaches to controlling the extraction of groundwater at two levels: the macro, or basin scale, and the micro scale of individual rights. This part also deals with four key emerging challenges in the context of groundwater extraction: permit- or licence-exempt wells; the emergence of a human right to water; integrated management of groundwater with hydrologically connected surface water and dependent ecosystems, and integrated management across political jurisdictions that share the same water source. These groundwater quantity issues have been particularly dominant in the legal discourse of the western US and Australia, where water scarcity is common and competition for water is high. Lastly, Part Three deals with groundwater quality protection, a regulatory concern in relation to both point-source pollution and, increasingly, diffuse sources of pollution.

The approaches taken in the western US, the EU and Australia to the groundwater law issues discussed here vary richly, not only in terms of the legal principles and tools available, but also in the extent to which they have developed and matured. The fundamental aim of this chapter is to highlight several key emerging issues that regulators, in particular, must consider and confront in groundwater management, and a range of potential legal approaches to these issues.

We draw on examples from each of the three focus regions in each part of the chapter, but in each part, emphasise the experience of jurisdictions in which the subject issue is particularly critical. Accordingly, in describing groundwater quantity concerns, we emphasise the experience of the western US and Australia, presenting these first; and in describing groundwater quality concerns, we emphasise the experience of the EU and the western US, presenting these first.

A final note: a comprehensive treatment of groundwater law, and notable subjects within it, lie outside the scope of this chapter. These include legal aspects of groundwater monitoring, trading, enforcement, pricing, managed aquifer recharge, stakeholder involvement in management, and non-regulatory aspects of groundwater law, such as private legal actions.

## 7.2 Envisioning Groundwater in Law: Its Nature and Ownership

### 7.2.1 What Is Groundwater, for the Purposes of the Law?

Different legal systems conceive of groundwater differently. The way in which groundwater is defined is of central importance in groundwater law. Too narrow a legal definition can unduly constrain the reach of the law, putting important resources beyond its control. An overly broad definition could complicate administration of the law if it means that permission is required to undertake activities affecting resources that are not, in fact, subject to concern about depletion or contamination.

Definitions of groundwater vary along several dimensions. Key points of difference include whether the definition includes water in the unsaturated zone, as well as in the saturated zone of the soil profile; whether it includes saline water or only freshwater; whether there is a depth limit to the water that is considered "groundwater"; the extent to which the definition includes things that are associated with groundwater, like the aquifer structure; how to distinguish surface water and groundwater where they are subject to different allocation arrangements; whether to distinguish between naturally occurring groundwater and groundwater that has been "artificially" stored using managed aquifer recharge; and how different administrative units of groundwater are defined. While these issues are too numerous to discuss in detail here, some examples of this variation are given here to illustrate notable approaches.

Law plays a unique place in defining groundwater in western US states—because the legal view can differ so radically from the scientific view. Some western US states draw complex, narrow legal distinctions between different legal "types" of groundwater, treating some groundwater (often called "percolating" groundwater) differently to groundwater that is closely connected to a river (often called "underflow", "subflow" of a surface stream, or "underground streams"). These distinctions bear no resemblance to geological reality (Klein 2005). Different allocation regimes and rules can apply to each legal "type" of groundwater, and the geographical boundaries of these types are rarely clear. This can result in a troublesome lack of clarity about exactly what legal regime applies to groundwater in a particular location—confusion that may only be able to be resolved through extensive technical studies or litigation (Sax et al. 2006).

Among the regions under discussion here, arguably the broadest definition of groundwater is found in Australia's federal *Water Act 2007*. That legislation defines "ground water" as "(a) water occurring naturally below ground level (whether in an aquifer or otherwise); or (b) water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there; but does not include water held in underground tanks, pipes or other works". "Water resources", which are the basis of administrative planning units, are defined extremely broadly to include, among other things, "ground water", an aquifer whether or not it currently has water in it, and "all aspects of the water resource (including water, organisms and other components and ecosystems that contribute to the physical state and environmental value of the water resource" (sub-section 4 (1)). The broad definition of groundwater clearly includes water artificially stored in aquifers using managed aquifer recharge, and the broad definition of water resources clearly indicates the importance of dependent ecosystems, including those that depend on groundwater, within the Australian federal water governance framework.

Within the European Union, the EU Water Framework Directive (adopted by the Council representing EU Member States and the European Parliament) provides a framework for water management, including groundwater. It should be stressed that each country of the 28 EU Member States must transpose EU directives into their national laws but that the practical implementation remains each nation's responsibility. The WFD defines groundwater more narrowly than does Australia's federal Water Act, as "all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil" (Article 2, item 2). The Directive also refers to a "Body of groundwater", which is a distinct volume of groundwater within an aquifer or aquifers. This volume is generally used to define administrative reporting units. Some Australian states take a similar approach, for example, defining groundwater as comprising only underground water in aquifers (e.g. sub-section 3(1), *Water Act 1989* (Victoria), Schedule 4, *Water Act 2000* (Queensland)).

### 7.2.2 Who Owns Groundwater?

The difficulty of conceiving of ownership in relation to water has been noted in very disparate jurisdictions as well as at the international level (Burke and Moench 2000; McKenzie 2009). Ownership of groundwater can be an emotion-charged issue: on the one hand, it is closely connected to land and ownership of land; on the other, it is often vital for public water supply systems and supporting ecosystems of high public value. In some places, groundwater has historically been treated very differently to surface water in relation to questions of ownership and allocation because its flowpath is less obvious, and even "secret" and "unknowable" (Klein 2005). This view was considered to justify the traditional English common law rule of absolute ownership of groundwater by overlying landowners, which was imported to both the US and Australia (Klein 2005; Gardner et al. 2009). Today, however, it may surprise some to know that across our three diverse focus regions, public or government ownership of groundwater is the norm, though principles for allocating it differ markedly between jurisdictions.

In the western US, with a few exceptions (as in Texas, where the English common law rule of absolute ownership still stands), the public as a whole owns the water and the state is its trustee. In other words, the state has a non-proprietary, regulatory interest in groundwater (Surett et al. 2013). A landowner generally has a proprietary right to *use* the water underlying the land, rather than ownership of the water itself (Surett et al. 2013). The question of whether water rights are property rights is not completely settled, however (e.g. Ross-Saxer 2010). Different states use different systems of allocation, relying on a variety of principles and procedures contained in statues and judge-made law. The doctrine of prior appropriation, which applies in most western US states, gives greater reliability to groundwater rights that developed earlier in time, rather than treating uses as generally equal in reliability and subject to correlative reductions in reliability in conditions of scarcity. Other systems are "correlative" groundwater rights among overlying landowners in California and Nebraska; and absolute ownership in Texas (Chapman et al. 2005). Judicial allocation necessarily involves court processes, and litigation has the potential to be lengthy and expensive—though this is not always the case, particularly where courts are used to formalise water rights in a basin, to which the parties have already agreed out of court.

Australian law also has its origins in the English common law, originally giving overlying landowners absolute, almost unrestricted rights to own and extract the resource. Legislative changes then vested groundwater in the Crown, and introduced a system of administrative regulation, under which the Crown grants individuals the right to use groundwater. Common law rights were generally abolished (Gardner et al. 2009). In some cases, statutes expressly sought to avoid the extensive water rights litigation that were perceived to occur under western US judicial allocation processes (Clark and Myers 1969). Rights to use groundwater in Australia are now generally considered property rights. Indeed, the creation of a highly regulated property rights system for water is an express premise of two decades of celebrated Australian water reforms aiming to improve economic efficiency and environmental sustainability (Gardner et al. 2009; McKenzie 2009).

Similar to Australia, in the EU, the entitlement to use groundwater (owned by the State) is given by public authorities through licences and permits which are issued for varying periods of time in different states. These are, however, not considered private property rights, but rather rights to exploit the resources in compliance with legally binding rules.

## 7.3 Controlling Groundwater Extraction

Establishing what groundwater is and who owns it is just part of the task of groundwater law. Its main function is to manage groundwater quantity by setting limits on total extraction to achieve a variety of objectives, and by controlling extraction as between individual users, in many cases by assigning individual rights to extract. The first step towards doing that is to decide what level of government to entrust with those regulatory tasks. The experiences of Australia and the EU show varying degrees of supra-state (federal and EU, respectively) involvement and coordination in certain high-level aspects of groundwater policy and law, but allocating water to individual users remains uniformly the task of lower levels of government. In the western US, the federal government has almost no formal role.

### 7.3.1 Who Regulates Groundwater Quantity?

Different jurisdictions allocate responsibility for regulating groundwater differently as between local, state and federal governments. Broadly, the locus of responsibility for groundwater quantity regulation reflects the general degree of acceptance of centralised government in each region, with responsibility tending to lie higher in government hierarchies in the EU and Australia and lower in the western US.

Western US states are generally responsible for regulating groundwater quantity, though in some states (as in Nebraska and most regions of California), this role is assumed by local governments. The federal government is directly involved in groundwater quantity concerns to a much lesser degree, for example, through funding mechanisms (Leshy 2008b).

Until very recently, Australia approached groundwater quantity regulation in much the same way: states had carriage of water allocation issues, and federal influence was felt mainly through funding mechanisms. However, after over a decade of federal water policy driven by economic incentives offered to the states, the federal *Water Act 2007* introduced a much more direct federal role. This is particularly so in the Murray-Darling Basin, an agriculturally and ecologically critical basin the size of France and Spain combined. Under arrangements that are yet to come fully into effect, the federal government sets Basin-wide limits on surface water and groundwater extraction, while states continue to allocate water to individual users within those overall caps.

In contrast to western US states (among which there is no coordination on groundwater quantity administration) and Australian states (among which there is coordination in policy, through the National Water Initiative, but relevant overarching law only in the Murray-Darling Basin), the EU's Water Framework Directive more strongly coordinates the regulation of groundwater quantity among Member States by establishing goals and planning processes in supra-national law. Actual water allocation is carried out by different authorities and agencies at different levels.

The issue of regulatory responsibility aside, the key substantive function of groundwater law is to manage groundwater extraction to achieve particular objectives. This can occur at both a macro- (i.e. basin-) scale, or at the level of individual rights to extract the resource. Though not discussed here, another focus of groundwater quantity law is requiring well spacing to control interactions between wells, and regulating well construction methods to prevent pollution.

### 7.3.2 Macro-Level Controls: Establishing Groundwater Withdrawal Limits Through Plans and Other Means

Jurisdictions use a variety of principles for establishing overall (e.g. basin-wide) withdrawal limits that restrict the allocation of groundwater rights—concepts like "safe yield" (western US), "good groundwater status" (EU), and "environmentally sustainable diversion limits" (Australia). In some cases, these overall withdrawal limits are established by management plans—an approach strongly favoured in Australia and the EU.

In most western US states, there is a weaker focus on overall basin extraction limits than in Australia or the EU, perhaps because of the absence of a water planning tradition (Chapman et al. 2005), and reliance on a common law tradition of water allocation. A disadvantage of the western US common law approach in contrast to Australia's water allocation planning approach is the relative difficulty of changing vital concepts like the principles that limit extraction, and how those principles are exercised in a particular year, to match changing water availability and also the modern recognition of the environmental water needs of groundwater-dependent ecosystems (Pilz 2010).

**Walnut Creek Intensive Groundwater Use Control Area, Kansas**

In the middle of Kansas, Cheyenne Bottoms lies on one of the busiest, globally significant shorebird migration paths. During their spring migration, about 45 % of North America's shorebird population, up to 600,000 individuals, use these wetlands, which are the largest in the interior US. By 1989, groundwater pumping to support the agricultural economy surrounding the wetlands had depleted Walnut Creek, the source of a surface water right held by the Kansas Department of Wildlife and Parks to water the wetlands. They were completely dry during the height of spring migration (Hays 1990). In response to these effects, the Kansas water rights administrator, the State Engineer, took the unprecedented step of declaring an "intensive groundwater use control area" and establishing rules to ban new groundwater pumping, cut back on existing groundwater rights, and introduce a "cap and trade" system for irrigation water rights. At the time, farmers predicted that groundwater pumping restrictions would have devastating economic effects. However, a 2011 economic analysis suggests that the initially significant economic effects of these rules diminished rapidly, so that in the long-run, producers made the same amount of money from crops while using less water (Golden and Leatherman 2011).

Where they exist, water plans in the western US tend to be used as water supply planning tools "designed to insure that adequate water is available for certain kinds of uses" (Wadley and Davenport 2013) rather than tools for setting basin-scale limits on water allocation. California provides an example of this approach: the California Water Code provides for various kinds of water management plans, including groundwater management plans, but these generally do not affect groundwater allocation (Nelson 2011b). Some western US states that have made recent changes to their groundwater management regimes have introduced the concept of water plans that are capable of constraining groundwater allocation to within cumulative caps (as in groundwater planning processes that aim to achieve "desired future conditions" in Texas (Witherspoon 2010)). Some other western states have water plans that affect groundwater allocation in a few designated groundwater areas that are recognised to require special management (e.g. Intensive Groundwater Use Control Areas in Kansas (Sophocleous 2012; and see text box)). In some eyes, a water planning approach is highly controversial, interpreted as an attack on a "pure" prior appropriation system, where seniority and "beneficial use" are the major determinants in allocating water (Wilkinson 1991).

Rather than using a planning mechanism, western US states tend to express overall extraction limits through state statutes and sometimes through judicial precedent, though on occasion neither is particularly clear. Some western US state statutes explicitly limit extraction to "safe yield"—roughly, constraining groundwater extraction to the level of natural and artificial recharge (e.g. Arizona Revised Statutes section 45-561(12), 45–562)—or some variation of that concept. However, as a technical concept, safe yield has been discredited as a management tool capable only of protecting against groundwater over-exploitation, since it ignores discharge points at surface water bodies and ecological users of groundwater (Alley et al. 1999). Some states increase or decrease the allowable extraction above or below the level of recharge by qualifying the concept of safe yield to include other aspects, for example, those related to economics and water quality impacts. In Washington, safe yield prohibits the state from granting appropriative rights beyond the basin's capacity to yield water within a reasonable or feasible pumping lift in case of pumping developments, or within a reasonable or feasible reduction of pressure in the case of artesian developments (Revised Code of Washington § 90.44.070). In Utah, safe yield means extracting the amount of groundwater that can be withdrawn from a basin over a period of time without exceeding the long-term recharge of the basin or unreasonably affecting the basin's physical and chemical integrity (Utah Code Annotated § 73-5-15). Generally speaking, however, environmental considerations in relation to groundwater quantity (i.e. seeking to maintain some portion of natural basin discharge that supports ecosystems) have not yet become a prominent consideration in setting basin-scale limits on extraction in the western US.

In Australia, macro-scale extraction limits are set by statute, usually through legislatively prescribed water planning processes. Broadly, two major goals of national water policy are "to increase the productivity and efficiency of Australia's water use . . . and to ensure the health of river and groundwater systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction." (Preamble, *Intergovernmental Agreement on a National Water Initiative*). National assessments of the progress of states in achieving these goals have repeatedly found shortcomings in relation to groundwater, however (e.g. National Water Commission 2009, National Water Commission 2011).

Australian water statutes generally cite both environmental and socio-economic objectives (e.g. section 3, New South Wales *Water Management Act 2000*). They limit extraction in a basin to a level that reflects a combination of environmental and economic principles, with the balance between the two varying depending on the jurisdiction. The federal *Water Act 2007* gives an example of an environment-led limit: under that legislation, a legally binding federal management plan for the Murray-Darling Basin requires states to ensure that aggregate groundwater pumping does not exceed "sustainable diversion limits" set to reflect "an environmentally sustainable level of take" (section 23). Key elements of that term, however, remain undefined in the legislation, and have been the subject of contestation. By contrast, the state of Victoria provides for "permissible consumptive volumes" to be set for groundwater administrative units without detailing the criteria to be applied to set these limits (section 22A, *Water Act 1989*), and they have not traditionally been set with regard to ecological water requirements. While Australian jurisdictions strongly emphasise the value of pre-planning acceptable extraction volumes, and constraining allocation through licences accordingly, some states do not impose allocation plans and general controls on groundwater extraction in basins that are only lightly exploited, preferring to wait until more intensive exploitation occurs before undertaking the technical work necessary to nominate extraction limits (e.g. prescribed water resources in South Australia: sections 76, 125, *Natural Resources Management Act 2004*).

In the EU, the Water Framework Directive sets a groundwater quantity goal of achieving "good quantitative status" for all water bodies by 2015. This will be achieved if the long-term annual average rate of abstraction is compensated by the aquifer recharge. This definition is complemented by principles that go beyond traditional "safe yield" concepts. The status definition also implies that the abstraction should not lead to alterations in flow directions which would result in saltwater or other intrusion. In addition, the level of groundwater should not be subject to anthropogenic alterations such that it would result in failure to achieve the environmental objectives (good chemical and ecological status) for associated surface waters, any significant diminution in the status of such waters, and any damage to terrestrial ecosystems which depend directly on the groundwater body. The policy framework opens the possibility for the Member States to use artificial recharge, providing that this does not jeopardise the quality of the groundwater.

As a general observation, to a greater or lesser degree, depending on the state, there seems to be a general movement towards basin-wide withdrawal limits that take some account of the impacts of extracting groundwater on the environment. This is quite a historical shift, which has generally mirrored the inclusion of such considerations in earlier surface water frameworks, or in a few cases occurred alongside it. This shift is proving much more advanced in Australia and the EU, at least on paper, than is the case in the western US, where often highly developed environmental protections for surface water are not replicated in relation to groundwater. The ease of modifying overarching principles through statute- and water plan-based processes may be one factor explaining this. Another might be the political difficulty of constraining economically important and water-intensive agricultural sectors in the western US, which have a much greater dependence on groundwater than does agriculture in most European countries or Australia (van der Gun 2013).

### 7.3.3 Micro Level Controls: Rights, Entitlements and Licences

Other than through basin-scale limits on extraction, the other major way in which groundwater law controls groundwater pumping is through rights, entitlements and licences at the scale of the individual groundwater user. Most jurisdictions within our focus regions require a person to obtain a right or entitlement to extract groundwater for particular end uses in all or many geographic areas. Notable exceptions to this are California and Texas in the western US, which do not generally require that a person obtain a permit to use groundwater, even for very large uses, except in small geographic areas. The requirements to obtain a permit or licence to use groundwater, and the processes involved, vary quite dramatically among our three focus regions, as well as within them (Patrick and Archer 1994; Bryner and Purcell 2003; Chapman et al. 2005; Gardner et al. 2009).

Western US groundwater allocation regimes tend to focus on a relatively narrow range of considerations that emphasise the human, rather than the environmental impacts of extracting groundwater. When considering an application for a permit, western US decision-makers commonly must consider: whether water is available for appropriation, the possibility of impairing existing rights, the applicant's ability to put the water to immediate beneficial use, public interest considerations, which are often undefined, and water conservation considerations (e.g. Idaho Code § 42-203A). A third party usually has strong rights of review; often, they not only have the right to protest a licensing decision, but in doing so, trigger a public hearing on the matter (e.g. Idaho Code § 42-203A, Montana Code Annotated §§ 85-2-308, 85-2-309). However, mirroring arrangements in relation to basin-scale extraction limits, in very few jurisdictions are environmental matters explicitly mentioned as a groundwater permitting consideration (e.g. Montana Code Annotated § 85-2-311(3)(b)(vi), Idaho Administrative Code § 37.03.08.045(e)(ii); North Dakota Century Code, § 61-04-06(4)(c)), and in any case, it appears that these matters are rarely considered with great rigour in practice.

By contrast, Australian legislation tends to produce long lists of matters that a decision-maker must consider in determining whether to grant a licence, with a heavier focus on environmental impacts. A key consideration is whether granting the licence would be consistent with any applicable overall consumptive limit for the area or applicable management plan (e.g. section 147, *Natural Resources Management Act 2004* (South Australia); section 40, *Water Act 1989* (Victoria)), which may itself contain further location-specific considerations relevant to licensing. Additional statutory considerations relate to the impacts on third parties of granting the proposed right to extract, and impacts on elements of the environment, such as water quality; water conservation policies; impacts on the aquifer structure (e.g. sections 40, 53, *Water Act 1989* (Victoria)); and impacts on connected resources, discussed further below. Opportunities for the public to be involved in the issuing of groundwater licences—and the emphasis that agencies place on this form of participation—are often relatively limited, with most of the focus of public participation being at the water planning stage (Nelson 2013). This may be problematic where the effects of extracting groundwater—particularly ecological effects—are very localised, and likely able to be anticipated only by locals. Local-scale groundwater-dependent ecosystems (GDEs) are unlikely to have been captured in macro-scale planning processes, and are not guaranteed to be addressed by centralised decision-making (Nelson 2013). Recent efforts to map GDEs at a fine scale (Bureau of Meteorology (Australia) 2013) may go some way towards addressing this danger by making this information easily available to decision-makers and the public.

The relative paucity of western US legal arrangements in relation to water planning, basin-scale caps, and even the brevity of permitting considerations can be explained in part by its very different conception of the role of time, compared with Australia. Rather than focusing heavily on prospective caps or groundwater permitting considerations, western US groundwater law deriving from prior appropriation principles controls the impacts of groundwater extraction primarily by looking backwards. That is, it seeks to avoid over-pumping by curtailing the exercise of a groundwater right that has been found to impair an earlier water right. Dangers with this approach lie in the political difficulty of reducing established uses, and dealing with the time lags that can separate ceasing to pump groundwater and the remediation of adverse impacts.

In the EU, authority to pump groundwater is generally given through permits that refer to the quantity of water abstracted and/or pumping capacity. The permits are closely linked to the risks of not achieving the Water Framework Directive's goal of "good quantitative status", i.e. implying that the level of groundwater in the groundwater bodies is such that the available groundwater resource is not exceeded by the long-term average rate of abstraction. This implies that issued exploitation licences are operated in such a way that they comply with the good status objectives (i.e. restrictions may be imposed in case of water scarcity).

### 7.3.4 The Challenge of Exempt Uses

Permit or licence-exempt groundwater uses can be a significant governance issue, in that they escape many standard legal controls, and may pose a cumulatively significant draw on the resource. Dealing with the potential impacts of such uses has been a particular issue in the western US and Australia (Bracken 2010; Sinclair Knight Merz et al. 2010). The particular end uses that are exempt from the general requirement to obtain a permit or licence vary from place to place. Uses of groundwater for domestic use and livestock watering are an important use category that rarely requires a permit in Australia and the western US (Bracken 2010; Sinclair Knight Merz et al. 2010).

In addition to the problem of many small exempt uses, sometimes even large individual uses of groundwater are exempt from regular groundwater licensing or permitting processes. An important example is groundwater produced as a by-product of extracting coal seam gas, or CSG (also known as coalbed methane). CSG production has raised concerns in relation to its groundwater impacts in both the western US and Australia (National Research Council (U.S.). Committee on

Management and Effects of Coalbed Methane Development and Produced Water in the Western United States 2010; Nelson 2012b). Petroleum and gas legislation in the Australian state of Queensland, where much of Australia's CSG production occurs, explicitly enables CSG producers to withdraw an unlimited amount of groundwater as part of their CSG activities, without requiring a water entitlement (section 185(3), *Petroleum and Gas (Production and Safety) Act 2004*). The same position was recently reversed in Colorado after a state Supreme Court decision (*Vance v. Wolfe*, 205 P.3d 1165 (Colorado 2009)). Similar issues have arisen in other western states (Klahn and Tuholske 2010; Valorz 2010).

### 7.3.5 The Challenge of a Human Right to Water

Whereas exempt groundwater uses can challenge groundwater governance by evading regular controls, nascent concepts of a human right to water could add further complexity to groundwater administration by conferring a different sort of special status on select groundwater uses. There are many areas of uncertainty in the meaning and practical implementation of a human right to water, in general (Good 2011). Regardless of the jurisdiction, key issues in relation to operationalising a human right to water will be its possible fiscal implications, the precise obligations that it creates, on whom, and how the right would be enforced (Thor 2013). A human right to water seems likely to attach to relatively small uses, like direct consumption and sanitation, which likely already benefit from permit-exempt status in many areas. Accordingly, new governance issues associated with the right seem more likely to be associated with groundwater quality, than groundwater quantity. An exception to this might be situations in which large-scale groundwater pumping for other uses affects the availability of water sources that are used to satisfy the human right to water. In any case, a human right to water is an emerging issue which each of the focus regions will likely need to address in the future.

Internationally, various political statements acknowledge a "right to water", including a resolution by the UN General Assembly (Thor 2013). Our focus regions take different approaches to this issue. There is no explicit reference to a human right to water in EU law but the first recital to the Water Framework Directive says "Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such", which is an implicit reference to human rights and principles of sustainability. Similarly, in Australia, a human right to water is not thought to be recognised at the federal level, but it has been argued that it could include principles of sustainability that would have a bearing on groundwater management, were it recognised (Good 2011).

California law has been more explicit. The state recently recognised a right to water in statute (Assembly Bill 685, codified as California Water Code § 106.3), though its formulation is relatively weak. AB 685 declares that it is state policy that every human being has the right to clean, affordable, and accessible water for human consumption, cooking, and sanitary purposes. However, the only duty that AB 685 imposes is a duty of "relevant" state agencies to "consider" the state policy on the human right to water when revising, adopting, or establishing policies, regulations, and grant criteria. It does not expand any state obligation to provide water, require the development of additional water infrastructure, or create an enforceable right for water system customers to demand immediate access to safe and affordable water. Though the precise legal implications of the law are not yet clear, recent focus on the lack of access to clean water of many disadvantaged communities in California, who rely on contaminated groundwater (Salceda et al. 2013), promises that it will be an important area of future legal development.

### 7.3.6 The Challenge of Connecting Groundwater Abstraction to Surface Water and Ecosystems

Integrating different elements of the environment, institutions, and actors is a noted challenge in water and environmental law (Klein 2005; Godden and Peel 2010; Thompson 2011). A particular challenge for groundwater law is how to deal with the relationship between groundwater and surface water—specifically, how abstraction of one should be controlled due to impacts on the other—particularly where these connections are affected by significant technical uncertainty. In general, the key issue is how groundwater pumping impacts rivers (though withdrawing surface water may also affect groundwater systems). A major related challenge is making legal provision for integrating groundwater with its environment, that is, making legal provision for ecological water requirements, thereby extending the now well-established concept of protected in-stream flows to groundwater. In most jurisdictions, this is an emerging and unsettled area of law, which seeks to address the water requirements of species and ecosystems that depend entirely on groundwater, as well as those that are associated with streams that receive water from groundwater-derived baseflow. The experiences of our focus jurisdictions demonstrate that key issues in determining a regulatory response to integrating groundwater, surface water and ecosystems will be determining trade-offs between using a complex, accurate, relatively certain, but administrative expensive mechanism (as in some states of the western US); and using broader, simpler, cheaper mechanisms, which offer arguably less certain results (as in Australia).

Western US mechanisms for integrating groundwater and surface water are arguably the most developed of the focus regions. They are also probably the most expensive to administer, since they require case-by-case technical assessments. Many western US states establish a threshold for the maximum proportion of the water withdrawn by a well that is predicted to be captured from a river over a certain period of time. States differ radically in the degree to which they will permit groundwater pumping to “impair” surface water rights. The relevant proportion in Colorado, for example, is 0.1 % of the annual pumped volume within 100 years of continuous withdrawal (Hobbs Jr 2010). Oregon, on the other hand, adopts a default threshold assumption that a well would usually cause substantial interference with a river if it is located less than a mile from the river, and derives 25 % of the withdrawal from the river within 30 days (Oregon Administrative Rules § 690-009-0040). States that have low regulatory thresholds for acceptable impairment of surface water rights tend to use flexible market-type mechanisms to enable groundwater pumpers to offset these impacts, and thereby meet the regulatory requirements for having their development proceed.

By contrast with protections for surface water rights, protections for (GDEs) are at a very early stage of development in the western US. They are achieved chiefly by way of principle-based thresholds for impairment, such as a "public interest" test for granting a groundwater permit that can include protections for fish and wildlife (e.g. Idaho Administrative Code § 37.03.08.045(e)(ii), North Dakota Century Code § 61-04-06(4)(c)). With more development, the public trust doctrine—which in most states applies only to certain surface waters, rather than groundwater—could provide a promising route to protecting GDEs (Craig 2010; Spiegel 2010).

**Protections for GDEs in the Blue Mountains, New South Wales**

Not far from the suburban sprawl of Sydney, Australia, lie the Blue Mountains, which have attained World Heritage status on account of their biodiversity values, cultural values, geodiversity, water production, and wilderness values. A key threat to the area's GDEs, particularly hanging swamps, comes in the form of new groundwater wells. The sensitivity of the ecosystems have warranted not only a ban on commercial wells in the Blue Mountains Sandstone Groundwater Management Area in 2007, but also short-term restrictions on the use of existing wells (NSW Office of Water 2011). Most significantly, given the generally high degree of reverence for domestic use of groundwater (see 'The challenge of exempt uses'), the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources (Sydney Basin Blue Mountains Groundwater Source) bans the granting or amending of bore approvals within 100 m of listed, high priority GDEs in the case of "bores used solely for extracting basic landholder rights", and 200 m for other uses; generally within 40 m from streams; and within 100 m from the top of an escarpment (clause 41).

Australian jurisdictions tend to use simpler volumetric or spatial thresholds to protect GDEs, such as clear drawdown limits or no-go zones for new wells around high-priority GDEs (see text box); or volumetric limits on groundwater pumping in a basin, where the limit is calculated to take into account acceptable impacts on rivers or other GDEs (Tomlinson 2011; Nelson 2013). In rare cases, caps on consumptive water use or rules that prevent extraction in response to water level triggers may cover both surface water and groundwater, where interaction effects happen over relatively short time-frames (e.g. Government of New South Wales 2010; Goulburn-Murray Water 2011). A further form of protection is offered by broad statutory considerations, such as requirements to have regard to environmental impacts when a decision-maker is considering a licence application (Nelson

2013). These approaches tend to require less case-by-case technical analysis than in the western US, but may offer less certain local protections, either because they apply at a macro level (e.g. large-scale volumetric limits), or because their requirements are not specified in detail (e.g. broad statutory considerations).

The EU's Water Framework Directive addresses groundwater-surface water interactions by incorporating connections in its key goal: achieving "good quantitative status" implies that impacts of pumping groundwater should not result in alteration of status of associated surface waters or in any damage in groundwater-dependent terrestrial ecosystems. This regulatory mechanism is, in principle, well established. The extent to which it has been achieved will be evaluated in 2015 in consideration of these possible impacts.

### 7.3.7 The Challenge of Connecting Groundwater Abstraction Across Boundaries

In addition to integrating different water sources and users, groundwater law frameworks also face the significant challenge of dealing with groundwater management in the cross-boundary context. This manifests, first, as rules for sharing cross-boundary aquifers; and second, as an allocation of responsibility for surface water depletions experienced in one jurisdiction, caused by upstream pumping of connected groundwater in another jurisdiction. Our focus regions illuminate several regulatory options for making these connections: proactive formal legal arrangements designed to prevent conflict, which may or may not involve creating a new regional institution; litigation to resolve conflicts; or, in some cases, a lack of coordinated management.

In the western US, litigation-based solutions to cross-boundary groundwater issues tend to be relatively common, and pro-active formal legal arrangements, at least at the interstate level, fairly rare. In particular, the impact of pumping groundwater on interstate rivers has been a key issue subject to significant litigation. Lengthy litigation has dealt with how groundwater pumping affects surface water delivery obligations under multiple interstate agreements, which do not explicitly deal with groundwater (Hathaway 2011; Thompson 2011). In some cases, this litigation has resulted in multi-million dollar damages being paid by upstream groundwater pumping states to downstream states. Such litigation in some cases has been followed by comprehensive management arrangements that seek to avoid similar problems recurring, including integrated surface water-groundwater technical models and monitoring programs. This litigation has proven to be a key driver of intrastate efforts to integrate the management of groundwater and surface water (Nelson 2012a).

Although litigation-based management of transboundary groundwater-surface water resources has proven the norm in the western US, the recent agreement between eight US states and two Canadian provinces governing management of the Great Lakes, and connected groundwater and tributaries takes a promising, different approach (*Great Lakes-St. Lawrence River Basin Water Resources*

*Compact*, effective 2008). The Compact applies to "Waters of the Basin", which are defined to include tributary groundwater (Article 103). The Compact establishes a central authority for management and implementation, and applies a common "decision-making standard" in relation to signatories regulating water uses within their territories (Article 203), but at the same time, grants them a relatively high degree of autonomy (Hall 2006).

In shared groundwater basins in the western US, which lack the complexity of highly connected surface water, "divided administration is the status quo" (Davenport 2008). Major interstate aquifers, like the High Plains Aquifer System (which includes the Ogallala Aquifer) underlying parts of South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, are administered by each state under separate arrangements. There is no formal coordination of the sort found in interstate river basin commissions or compact arrangements (Sophocleous 2010; Hathaway 2011), and no Supreme Court litigation to apportion the groundwater (Leshy 2008a). Rather, a situation of "de facto groundwater allocation" through "a combination of unilateral actions and lack of action" occurs in many basins, for example the Hueco Bolson Basin underlying New Mexico, Texas and Mexico; in others, some mechanisms like data sharing exist, but cooperation is notably lacking (Hathaway 2011, p. 106). Commentators have noted that interstate groundwater conflicts are developing, particularly where groundwater use is growing (Hathaway 2011).

Australia's management challenges in relation to transboundary aquifers are relatively simple, since it lacks international groundwater boundaries and has relatively few states. The most significant aquifer that crosses interstate boundaries is the Great Artesian Basin, the world's largest artesian basin (Mackay 2007). Coordinated management of the basin occurs under the Great Artesian Basin Coordinating Committee, which has a largely advisory role, rather than regulatory functions. Its main focus has been a scheme to fund the capping of artesian wells that previously were allowed to run freely, causing a loss in aquifer pressure (Mackay 2007). At a smaller scale, a groundwater border agreement between the states of Victoria and South Australia, for example, controls depletion of a non-recharged aquifer by bores other than stock and domestic bores by setting zone-based caps on extraction and drawdown (Schedule 1, *Groundwater (Border Agreement) Act 1985* (Victoria)). It takes effect through state-level licensing decisions within a 40 km-wide cross-border area of the aquifer, which must be made consistent with the Agreement.

The EU Water Framework Directive deals with interjurisdictional groundwater issues in a notably more proactive and structured way than has been the case in either Australia or the western US. It requires Member States to establish international river basin districts, thus requiring cross-boundary cooperation for overall water management, including groundwater (article 13, items 2). It also recommends Member States to establish appropriate coordination with non-EU countries in river basins crossing the boundaries of the EU (this is however not as strict as the first regulation, as the article says: the Member States "shall endeavour to establish cooperation") (article 13, item 3). This is the only reference to cross-boundary aquifer situations concerning quantity aspects. In addition to this, the Groundwater Directive (daughter directive to the WFD) requests Member States to coordinate the establishment of threshold values (groundwater quality standards) in bodies of groundwater within which groundwater flows across a Member State's boundary. Similarly to the WFD, it also recommends ("shall endeavour") coordination with non-EU countries sharing a transboundary aquifer for the establishment of groundwater quality standards (threshold values).

## 7.4 Controlling Discharges of Pollution to Groundwater

Groundwater quality is a subject matter that regulation often treats separately to groundwater quantity. This occurs despite the physical connections between groundwater quantity and quality: polluting groundwater effectively reduces the quantity of usable groundwater, and pumping groundwater can cause quality problems in the form of spreading contaminant plumes and seawater intrusion. Groundwater quality and quantity are regulated under very different frameworks in Australia and the western US. This section briefly describes these frameworks, and introduces the EU's more integrated approach to controlling polluting discharges to groundwater. Key elements of regulatory frameworks for groundwater quality are setting quality goals, and regulating potentially polluting activities to achieve those goals—both point and diffuse sources of pollution.

### 7.4.1 Macro-Level Groundwater Quality Goals

Jurisdictions in each of our focus regions differ in the goals that they set for groundwater quality, the methods of setting those goals, and divisions of regulatory responsibility. In the EU, the goal and definition of "good chemical status" are given in the Water Framework Directive (article 2, item 25 and Annex V, Table 2.3.2) and elaborated in a "daughter directive" which was adopted in 2006 (Directive 2006/118/EC). In this context, the compliance regime is based on quality objectives (compliance with relevant standards, no saline intrusion) that have to be achieved by the end of 2015. The direction chosen is based on compliance with EU-wide groundwater quality standards (covering nitrates and pesticides) which reinforce the parent directives (i.e. the standards are to be applied across the EU). Regarding other pollutants, the adoption of numerical values at Community level was not considered to be a viable option, considering the high natural variability of substances in groundwater (depending upon hydrogeological conditions, background levels, pollutant pathways, and interactions with different environmental compartments). Consequently, the regime of the "daughter" Groundwater Directive requests Member States to establish their own groundwater quality standards (referred to as "threshold values"), taking identified risks into account and a list of substances given in an annex to the Directive. Threshold values must be established for all pollutants that characterise groundwater bodies at risk of not achieving the good chemical status objective and this should be done at the most appropriate level, e.g. national, river basin district or groundwater body level. They concern not only pollutants that may be naturally present in groundwater but also synthetic pollutants. Regarding compliance, evaluation will be based on a comparison of monitoring data with numerical standard values (EU-wide groundwater quality standards and/or threshold values set by individual Member States).

In contrast to the EU's single, comprehensive legislative approach to regulating groundwater pollution, the US federal approach has been characterised as an inadequate "patchwork" (Thomas 2009). In relation to groundwater, the main US federal approach has been to regulate key activities that have the potential to pollute groundwater, as described below, rather than to set quality standards, for which it provides in the case of surface water under the Clean Water Act. A form of macro-level control is adopted, though, under the Safe Drinking Water Act. That Act provides for setting "maximum contaminant levels" for public water supply sources. In addition, its "sole source aquifer" program provides for the designation of aquifers that are the sole or principal source of drinking water for an area. The federal government may not fund a project that may contaminate such an aquifer, endangering public health. Under the Safe Drinking Water Act, states must also develop wellhead protection programs to prevent pollution near wellfields that provide public drinking water (Sax et al. 2006). A small number of US state laws mirror the Clean Water Act's approach to surface water protection, prohibiting the discharge of pollutants into groundwater (Thomas 2009). Australia's federal groundwater quality policy echoes, and has been influenced by, these approaches.

In Australia, the role of the federal government in groundwater quality is largely restricted to recommending policy, undertaking joint planning with states, and offering funding (Nelson 2011a). Though groundwater quality—mainly salinity—has been a traditionally strong concern in many parts of Australia, a recent decade of extreme drought ensured that most attention focused on groundwater quantity; federal groundwater quality policy is now significantly out of date. The *Guidelines for Groundwater Quality Protection in Australia* (GGQPA), a component of the *National Water Quality Management Strategy*, were published in 1995, and recent reviews have recommended that they be updated (Nelson 2010; Sundaram et al. 2010). Separate policies apply to protecting groundwater quality in specific contexts, such as managed aquifer recharge, the application of recycled water and drinking water standards. The basic approach promoted in the GGQPA is to assess a groundwater resource, set beneficial uses for the resource and accompanying quantitative or qualitative criteria, develop protection measures, and undertake monitoring (Chap. 5, GGQPA; Nelson 2010). Australian states shoulder the major regulatory burden in relation to groundwater quality. Goals for environmental quality (including groundwater quality) are generally set out in state-level environment protection policies, which may be binding or non-binding. They typically aim to protect region-specific "beneficial uses" or "environmental values" of the groundwater, consistent with national policy.

### 7.4.2 Micro-Level Controls: Diffuse and Point Sources

Jurisdictions commonly control the discharge of point-source pollutants to groundwater, but controls over diffuse sources of pollution uniformly have proven more challenging. In the EU, the compliance regime of the Groundwater Directive implies that values of groundwater quality standards (threshold values) should not be exceeded at any monitoring points in groundwater bodies. However, it opens the possibility for exceeding concentrations at one or more monitoring points providing that an appropriate investigation shows that the exceeding concentrations (e.g. point source pollution) are not considered to present a significant environmental risk, nor endanger the uses of groundwater. In addition, Member States are required to assess the impacts of existing plumes of pollution in groundwater bodies that may threaten their overall quality objectives, in particular plumes resulting from point sources and contaminated land. The Directive requests Member States to carry out trend assessments for identified pollutants in order to verify that plumes from contaminated sites do not expand, do not deteriorate the chemical status of the groundwater body (or bodies in case of grouping) and do not present a risk to human health and the environment. Non-legally binding guidance documents are used to guide Member States on assessing the condition of groundwater and related matters (e.g. European Commission 2007; Quevauviller 2008; European Commission 2009).

In Australia, macro-level groundwater quality goals are operationalised through pollution licensing processes, which generally apply only to point sources. State laws regulate potentially polluting activities, often requiring that an authorisation to undertake such an activity only be granted consistently with, or considering, legislative instruments that set out the beneficial uses of groundwater (e.g. section 47(1)(e) *Environment Protection Act 1993* (South Australia)). Water allocation planning processes may also include a requirement to consider beneficial uses (e.g. Tasmania Department of Primary Industries and Water 2009). Economic incentives to minimise pollution also appear in state laws in the form of fees for environmental authorisations that reward best practice (regulations 5CA, 5EA, Environment Protection Regulations 1987 (Western Australia)) and tradeable emissions schemes (e.g. Parts 9.3A *Protection of the Environment Operations Act 1997* (New South Wales)). State laws (as opposed to policies or funding programs) dealing with non-point source pollution take several forms, but are much less developed than those for point sources. They can appear as general statutory duties not to pollute the environment or cause environmental harm, supported by codes of conduct or "best practice" guidelines for non-point source activities; and statutory matters that land use planners must consider when faced with land use decisions. Voluntary guidelines, codes of conduct and self-regulatory approaches tend to be used more commonly, in practice, than mandatory obligations (Nelson 2011a). Remedial measures take the form of environment protection or abatement orders (Bates 2006).

As alluded to above, the US federal government's key water quality legislation, the Clean Water Act, does not apply to groundwater in terms of licensing point source discharges, though this is a somewhat contentious matter in relation to groundwater that is hydrologically connected to navigable waters, which are covered (Thomas 2009; Makowski 2012). Rather, the potential for groundwater pollution is addressed by a collection of federal legislation that applies to particular activities that may pollute groundwater. The federal *Safe Drinking Water Act* applies to licensing underground injection activities, including aquifer storage; the *Resource Conservation and Recovery Act* regulates solid waste including hazardous waste, and applies to underground storage tanks; and the *Comprehensive Environmental Response, Compensation and Liability Act* deals with remediating past contamination using a strict liability approach (Sax et al. 2006). Non-point sources historically have been dealt with using voluntary control measures, but there is evidence that federal encouragement of states to use more rigorous enforcement mechanisms is producing promising results (Nelson 2011a).

At the state level, jurisdictions take a variety of approaches to seeking to prevent groundwater pollution. California provides an example of a state that is generally regarded as having a promising approach to non-point source groundwater pollution, in particular. Its *Porter-Cologne Water Quality Control Act* gives the state direct power to regulate nonpoint sources, including agriculture. Regional water quality control plans set out water quality objectives and beneficial uses; waste discharges are subject to either general (based on discharge category) or individualised requirements based on the relevant basin plan and other factors (sections, 13241, 13263 California Water Code). Any person discharging waste, including from non-point sources, must report the discharge and pay an annual fee, unless a waiver applies (section 13260, California Water Code). Unfortunately, the temptation to grant waivers to agricultural non-point polluters has historically been irresistible (Nelson 2011a; Smith and Harlow 2011). More recently, examples of stronger controls on agricultural non-point source pollution of groundwater have arisen, notably requirements for certain categories of farms to have a farm water quality management plan, monitor and report on groundwater conditions, monitor and report on discharges, and have a nutrient management plan (California Regional Water Quality Control Board Central Coast Region 2012). Concerns over nitrate pollution have been instrumental in driving this approach (California Regional Water Quality Control Board Central Coast Region 2012).

## 7.5 Conclusion

This chapter sets out a framework of key issues that arise in groundwater law, with an emphasis on regulatory approaches adopted in the western US, Australia, and the EU. It will be apparent that these regions, and the jurisdictions within them, differ in many ways in their approaches to groundwater law—both controlling groundwater extraction and controlling discharges of pollution to groundwater. These differences begin at the most basic level of defining what groundwater is and who should regulate it, and establishing limits to groundwater withdrawal and groundwater pollution at the level of the basin and of individual users and polluters, respectively.

It is not possible to deem any one approach universally most effective or desirable for all situations, and we do not attempt to do so. We do, however, suggest a series of key issues that are likely to pose challenges to effective groundwater management, and that decision-makers should consider in establishing, evaluating, and revising their groundwater laws. In the experience of our three focus regions, these basic challenges include: dealing with groundwater uses that are exempt from licensing requirements; interpreting and applying the emerging notion of a human right to water; connecting groundwater abstraction to impacts on surface water and ecosystems; connecting groundwater abstraction across boundaries; and dealing with both diffuse and point sources of pollution.

While some of these issues have been of regulatory concern for some time, others have arisen over only several years, more recently. Despite the many differences between jurisdictions, they have one regulatory requirement in common: groundwater law must continue to evolve and adapt to newly emerging and dynamic challenges in groundwater management in order to effectively manage groundwater quantity and quality, now and in the future.



## References

Alley WM, Reilly TE, Franke OL (1999) Sustainability of ground-water resources: U.S. geological survey circular 1186. U.S. Geological Survey, Denver

Bates G (2006) Environmental law in Australia, 6th edn. LexisNexis Butterworths Australia, Chatswood

Bates B, Kundzewicz ZW, Wu S, Palutikof J (2008) Climate change and water: intergovernental panel on climate change technical paper VI. IPCC Secretariat, Geneva

Bracken N (2010) Exempt well issues in the west. Environ Law 40:141–253

Bryner G, Purcell E (2003) Groundwater law sourcebook of the Western United States. Natural Resources Law Center, University of Colorado School of Law, Boulder

Bureau of Meteorology (Australia) (2013) National atlas of groundwater dependent ecosystems. http://www.bom.gov.au/water/groundwater/gde/. Accessed 19 May 2014

Burke JJ, Moench MH (2000) Groundwater and society: resources, tensions and opportunities. Themes in groundwater management for the twenty-first century. Department of International Economic and Social Affairs, Statistical Office, United Nations, New York

California Regional Water Quality Control Board Central Coast Region (2012) Conditional waiver of waste discharge requirements for discharges from irrigated lands (Order No. R3-2012-0011). California Regional Water Quality Control Board Central Coast Region, San Luis Obispo

Chapman M, Glasser S, Gipsman J, Witte L (2005) U.S.D.A. forest service sourcebook of state groundwater laws in 2005. United States Department of Agriculture, Washington, DC

Clark SD, Myers AJ (1969) Vesting and divesting: the victorian groundwater act 1969. Melbourne Univ Law Rev 7:237–257

Craig RK (2010) A comparative guide to the western states' public trust doctrines: public values, private rights, and the evolution toward an ecological public trust. Ecol Law Q 37:53–198

Davenport JH (2008) Less is more: a limited approach to multi-state management of interstate groundwater basins. Univ Denver Water Law Rev 12:139–180

European Commission (2007) Common implementation strategy for the water framework directive (2000/60/EC): guidance on groundwater in drinking water protected areas. European Commission, Luxembourg

European Commission (2009) Common implementation strategy for the water framework directive (2000/60/EC): guidance on groundwater status and trend assessment. European Commission, Luxembourg

Folger JA (2010) From Australia to California: solving California's water crisis by applying lessons learned down under. Univ San Francisco Law Rev 45:243–264

Gardner A, Bartlett RH, Gray J, Carney G (2009) Water resources law. LexisNexis Butterworths, Chatswood

Garry T (2007) Water markets and water rights in the United States: lessons from Australia. Macquarie J Int Comp Environ Law 4:23–60

Godden L, Peel J (2010) Environmental law: scientific, policy, and regulatory dimensions. Oxford University Press, South Melbourne

Golden B, Leatherman J (2011) Impact analysis of the walnut creek intensive groundwater use control area. Kansas State University, Manhattan

Good M (2011) Implementing the human right to water in Australia. Univ Tasmania Law Rev 30: 107–143

Goulburn-Murray Water (2011) Upper ovens river water supply protection area water management plan. Goulburn-Murray Water, Tatura

Government of New South Wales (2010) Water sharing plan for the peel valley regulated, unregulated, alluvium and fractured rock water sources 2010. Government of New South Wales, Sydney

Grafton RQ, Landry C, Libecap GD, O'Brien JR (2009) Markets—water markets: Australia's Murray-Darling Basin and the US Southwest, International centre for economic research, working paper no.15/2009. International Centre for Economic Research, Torino

Hall ND (2006) Toward a new horizontal federalism: interstate water management in the great lakes region. Univ Colorado Law Rev 77:405–455

Hathaway DL (2011) Transboundary groundwater policy: developing approaches in the Western and Southwestern United States. J Am Water Resour Assoc 47:103–113

Hays J (1990) Cheyenne bottoms fight pits farmers against fowl. Wichita Eagle, 2 Dec 1990: p 1A

Hobbs Jr (2010) Protecting prior appropriation water rights through integrating tributary groundwater: Colorado's experience. Idaho Law Rev 47:5–22

Kemper KE (2007) Instruments and institutions for groundwater management. In: Giordano M, Villholth KG (eds) The agricultural groundwater revolution: opportunities and threats to development. CABI, Wallingford, pp 153–171

Klahn SA, Tuholske J (2010) Coalbed methane produced groundwater: a survey of western water law regulation. Water Rep 77:1–8

Klein C (2005) On integrity: some considerations for water law. Alabama Law Rev 56:1009–1070

Leshy J (2008a) Interstate groundwater resources: the federal role. West-Northwest J Environ Law Policy 14:1475–1498

Leshy JD (2008b) The federal role in managing the nation's groundwater. Hastings West-Northwest J Environ Law Policy 14:1323
Mackay J (2007) Groundwater as the Cinderella of water laws, policies, and institutions in Australia. In: Ragione S (ed) The global importance of groundwater in the 21st century: In the proceedings of the international symposium on groundwater sustainability, Alicante, 24–27 Jan 2006, National Groundwater Association, Westerville, pp 317–329
Makowski A (2012) Beneath the surface of the clean water act: exploring the depth of the act's jurisdictional scope of groundwater pollution. Oregon Law Rev 91:495–526
McKenzie M (2009) Water rights in NSW: properly property? Sydney Law Rev 31:443–463
National Research Council Committee on Management and Effects of Coalbed Methane Development and Produced Water in the Western United States (2010) Management and effects of coalbed methane produced water in the Western United States. National Academies Press, Washington, DC
National Water Commission, Australia (2009) Australian water reform 2009: second biennial assessment of progress in implementation of the national water initiative. National Water Commission, Canberra
National Water Commission, Australia (2011) The national water initiative—Securing Australia's water future: 2011 assessment. National Water Commission (Australia), Canberra
Nelson R (2010) The guidelines for groundwater protection in Australia: regulatory review (prepared for Geoscience Australia). Geoscience Australia, Canberra
Nelson R (2011a) Regulating nonpoint sourt pollution in the US: a regulatory theory approach to lessons and research paths for Australia. Univ West Aust Law Rev 35:340–384
Nelson R (2011b) Uncommon innovation: developments in groundwater management planning in California. Stanford University, Palo Alto
Nelson R (2012a) Instituting integration: findings of the comparative groundwater law and policy program's workshop 1. Stanford University, Palo Alto
Nelson R (2012b) Unconventional gas and produced water. In: Committee for economic development of Australia. Australia's Unconventional Energy Options, Committee for Economic Development of Australia, Melbourne, pp 27–40
Nelson R (2013) Groundwater, rivers and ecosystems: comparative insights into law and policy for making the links. Aust Environ Rev 28:558–566
NSW Office of Water (2011) Water sharing plan for the greater metropolitan region groundwater sources—background document. Government of New South Wales, Sydney
Patrick KL, Archer KE (1994) A comparison of state groundwater laws. Tulsa Law J 30:123–156
Pilz RD (2010) Lessons in water policy innovation from the world's driest inhabited continent: using water allocation plans and water markets to manage water scarcity. Univ Denver Water Law Rev 14:97–130
Quevauviller P (2008) Groundwater science and policy: an international overview. Royal Society of Chemistry, Cambridge
Ross A, Martinez-Santos P (2010) The challenge of groundwater governance: case studies from Spain and Australia. Reg Environ Chang 10:299–310
Ross-Saxer S (2010) The fluid nature of property rights in water. Duke Environ Law Policy Forum 21:49–112
Salceda A, Saied K, Zülow C, International Human Rights Law Clinic (2013) The human right to water bill in California. University of California, Berkeley, School of Law, Berkeley
Sax JL, Thompson BH Jr, Leshy JD, Abrams RH (2006) Legal control of water resources: cases and materials, 4th edn. Thomson/West, St. Paul
Sinclair Knight Merz, CSIRO, Bureau of Rural Sciences (2010) Surface and/or groundwater interception activities: initial estimates. National Water Commission, Canberra
Smith LN, Harlow LJ (2011) Regulation of nonpoint source agricultural discharge in California. Nat Resour Environ 26:28–32
Sophocleous M (2010) Review: groundwater management practices, challenges, and innovations in the High Plains aquifer, USA—lessons and recommended actions. Hydrogeol J 18:559–575
Sophocleous M (2012) The evolution of groundwater management paradigms in Kansas and possible new steps towards water sustainability. J Hydrol 414–415:550–559

Spiegel D (2010) Can the public trust doctrine save western groundwater? New York Univ Environ Law J 18:412–453
Sundaram B, Nelson R, Coram J (2010) Assessing the need to revise the guidelines for groundwater protection in Australia: a review report. Geoscience Australia, Canberra
Surett E, Dietz L, Larsen S (2013) Waters. In American jurisprudence, 2nd edn. West Group, St Paul
Tasmania Department of Primary Industries and Water (2009) Water resources policy #2005/1: generic principles for water management planning. Tasmania Department of Primary Industries and Water, Hobart
Thomas R (2009) The European directive on the protection of groundwater: a model for the United States. Pace Environ Law Rev 26:259–287
Thompson BH Jr (2011) Beyond connections: pursuing multidimensional conjunctive management. Idaho Law Rev 47:273–323
Thor E (2013) The human right to water in the United States: why so dangerous? Pac McGeorge Glob Bus Dev Law J 26:315–341
Tomlinson M (2011) Ecological water requirements of groundwater systems: a knowledge and policy review. National Water Commission, Canberra
Valorz NJ (2010) The need for codification of Wyoming's coal bed methane produced groundwater laws. Wyoming Law Rev 10:115–140
van der Gun J (2013) Groundwater abstraction estimates by country. In: Margat J, van der Gun J (eds) Groundwater around the world: a geographic synopsis. CRC Press, Leiden, pp 303–311
Wadley JB, Davenport JH (2013) The law of water. In: Powell on real property, vol 9. Matthew Bender & Company, Inc, New York
Wilkinson CF (1991) In memoriam: prior appropriation. Environ Law 21:xxix–xlii
Witherspoon T (2010) Into the well: desired future conditions and the emergence of groundwater as the new senior water right. Environ Energy Law Policy J 5:166–182

# Groundwater Regulation and Integrated Water Planning

8

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**Abstract**

The complex nature of groundwater and the diversity of uses and environmental interactions call for emerging groundwater problems to be addressed through integrated management and planning approaches. Planning requires different levels of integration dealing with: the hydrologic cycle (the physical process) including the temporal dimension; river basins and aquifers (spatial integration); socioeconomic considerations at regional, national and international levels; and scientific knowledge. The great natural variation in groundwater conditions obviously affects planning needs and options as well as perceptions from highly localised to regionally-based approaches. The scale at which planning is done therefore needs to be carefully evaluated against available policy choices and options in each particular setting. A solid planning approach is based on River Basin Management Planning (RBMP), which covers: (1) objectives that management planning are designed to address; (2) the way various types of measures fit into the overall management planning; and (3) the criteria against which the success or failure of specific strategies or interventions can be evaluated (e.g. compliance with environmental quality standards). A management planning framework is to be conceived as a "living" or iterated document that can be updated, refined and if necessary changed as information and experience are

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A.J. Jakeman et al. (eds.), *Integrated Groundwater Management*,
DOI 10.1007/978-3-319-23576-9_8

gained. This chapter discusses these aspects, providing an insight into European Union (EU), United States and Australia groundwater planning practices.

## 8.1 Introduction

The complex nature of groundwater calls for emerging groundwater problems to be addressed through integrated management approaches designed to change the way people view and use the resource. Three levels of integration are concerned: (1) within the hydrologic cycle (the physical process) including the temporal dimension; (2) across river basins and aquifers (spatial integration); and (3) across socioeconomic sectors at regional, national and international levels (Mostert et al. 1999). A fourth level of integration concerns the way scientific knowledge is used (Quevauviller 2008). The great range of the natural variability inherent to groundwater systems obviously affects management needs and options, i.e. from highly local management approaches to regionally-based approaches. The management scale hence requires an encompassing evaluation of available policy choices and options for each particular setting. This is more complex than for example, river basin management delineated using land surface, owing to a three-dimensional structure of the aquifer systems with often unknown and unmapped boundaries, and complex temporal responses (e.g. lags) of aquifer systems. General principles of integrated water-resource management, address groundwater management in the context of a strategic framework that encompasses these and other characteristics. This chapter provides an insight into integrated groundwater planning, with examples taken from the European Union Water Framework Directive (WFD–http://ec.europa.eu/environment/water/water-framework/index_en.html) River Basin Management Planning (RBMP) as well as groundwater regulations in effect in Australia and USA.

## 8.2 Challenges Linked to Groundwater Management

Fully integrated approaches for groundwater management may precipitate massive data collection and planning efforts, which, given the potential large size and scope, may be out of date before they are completed. As a result, the level of integration must be balanced against practical limitations and the often superior effectiveness of immediate action to address developing problems. Whole-system perspectives and adaptive management approaches are generally considered to be more practical than the ideal "fully integrated" approaches. Both approaches require a strong conceptual understanding of the natural groundwater conditions while also encompassing a broad array of physical, social, economic and institutional factors affecting water management needs and options. Institutions are often required to be knowledge-driven with broad access to data and information, and need personnel capable of articulating a broad interdisciplinary understanding of water management issues.

Therefore there is a need for flexibility in groundwater management. Because social, economic and hydrological systems are dynamic rather than static, and factors directly or indirectly affecting groundwater conditions vary greatly from place to place, integrated groundwater management is not amenable to a one-size-fits-all approach. This implies the development of a management framework that acknowledges social, economic and physical resource conditions important in different management areas (Burke and Moench 2000). National frameworks that attempt to specify smaller scale management details (e.g. spacing of wells, specific prices for water) will often enumerate actions that are inappropriate or unworkable at the local or even regional level. In contrast, national frameworks that focus on broad principles and provide clear administrative and/or legal guidance enable local or regional managers to flexibly tailor more workable and efficient solutions. This also facilitates effective participatory planning involving scientists, resource management specialists, stakeholders, and decision-makers.

Groundwater management complexity tends to increase with increasing spatial and temporal scale, which in turn encompasses a wider range of conditions in the groundwater system. Therefore, management activities carried out at the smallest scale and at the lowest administrative level (at which they can effectively be carried out) are easier and most effective to tackle. This tenet needs to be balanced against management decisions related to the large and connected nature of groundwater systems—connections that propagate local management activities into the larger system. That is, institutional views of recognizing and accounting for resource management areas reflect the physical scale at which groundwater systems function and, in this respect, clear management units are as important for the development of effective management institutions as they are for scientific understanding (e.g. river basin or "water body" as defined in the EU Water Framework Directive, see Sect. 8.9). Therefore, local management actions have to reflect wholesale aquifer dynamics and fit within a management framework that recognizes the aquifer as the primary unit for management of the resource. The challenge is to manage large aquifer systems with a single overarching scientific framework and clear objectives that will facilitate overall aquifer management and ensuring that local approaches are consistent with the overarching framework.

## 8.3 Integrated Water Management Framework

### 8.3.1 Water and Its Environment

The surface-watershed constitutes the basis of river basin management (RBM) in the framework of which groundwater may be managed in an integrated way. Although the groundwater and surface-water divide may not exactly align (e.g., Hunt et al. 1998; Winter et al. 2003), the system can be defined for management as the geographical area determined by the surface-watershed limits of the system of waters, including surface water and groundwater. Strong interactions usually exist between groundwater and surface water in the basin, between water quantity and quality, and between land and water, upstream and downstream. This means that hydrologic basins can be managed not only as a geographical area but as a coherent social and ecological system (Burke and Moench 2000). Such entities are considered open systems in that these systems interact continuously with the atmosphere (precipitation and evaporation, airborne pollution) and terminal receiving waters (e.g., wetlands, lakes, oceans).

Waters within these systems fulfill many important functions, such as water supply for households, industry and agriculture, navigation, fishing, recreation and ecological niches. Economic and social development and even life itself cannot be sustained without sufficient water at the right time and place and of sufficient quality. In addition, water has shaped and continues to shape the environment, eroding mountain areas, creating karst, transporting sediment and creating delta areas. It is an essential element of nature while being subject to variability caused by human activities or natural causes, e.g. climate change, which can lead to floods or droughts. Effective RBM has to tackle all these issues, i.e. RBM is much broader than traditional water management as it includes land-use planning, policy (e.g. agricultural) and integrated management principles for groundwater. It also covers all human activities that use or affect surface water and groundwater systems.

### 8.3.2 River Basin Management Objectives

River basin management (RBM) principles aim at ensuring the multifunctional use of waters in rivers and their basins for the present and future generations. Since the capacity of river basins to accommodate different uses is always limited, with effective management, priorities have to be set. In particular, basic human needs have to be safeguarded (i.e. water supply for drinking and basic hygiene) and environmental protection should be given a full place in RBM. Apart from that, other priorities depend on the natural, social and economic conditions in the particular basin. Four different management levels can be distinguished according to Mostert et al. (1999): operational management, the institutional framework, planning and analytical support. Only operational management affects river basins directly. The following sections provide more details about these four components and issues relating to transboundary aquifer management and public participation.

RBM is closely linked to decentralization, i.e. government authorities are brought as close as possible to individual citizens, allowing for local variation in response to local circumstances and preferences for the notion of "subsidiarity" (a principle that is fully embedded into the EU Treaty). This is also more efficient as decentralized government tends to be less bureaucratic—simply because of its size—and better informed about local circumstances. Decentralization is not possible, however, for tasks such as establishing the institutional structure and formulating policies that apply to a large region or Nation as a whole. However, decentralized governments should be involved with RBM because of their superior information on local conditions and because of their (usually) closer contacts with the population within the river basin. Decentralization may also not be possible if the decentralized governments lack the necessary management capacity. Solutions could include local capacity building and advisory services by specialized central governments.

## 8.4 Operational Management

Operational management embeds activities such as river regulation, constructing and operating water-supply infrastructure, reforestation projects, aquifer artificial recharge, etc. Operational management is linked to legal and policy requirements and guidelines and related measures. These may include emission controls of agricultural or industrial pollutants, abstraction controls, codes of good practices (e.g. Best Available Technologies, Best Environmental Practices, Best Management Practices), construction and/or rehabilitation projects and desalination plants. RBM may also address the behavior of different users/managers by explicitly forbidding, regulating or allowing certain activities (legislative or administrative instruments) in the basin and by offering economic (dis)incentives (economic or fiscal instruments) for some of these activities. Different resources are necessary to apply these instruments, such as financial, personnel, legal, appropriate policy directives and data.

### 8.4.1 Pollution Control

In a sustainable world, pollution control would be limited, i.e. emissions of contaminants of concern to the river basin would be close to zero. The main issue is how to approach this target and solve urgent pollution problems while ensuring that further pollution risks are prevented or limited. Regulations hence generally focus on programs for preventing or limiting inputs of pollutants into waters of the basin, e.g. control of point and diffuse sources of pollution through a combined approach based on emission controls using best available techniques, relevant emission values or best environmental practices (in the case of diffuse pollution) which are set out in relevant legislation (dealing with industrial, urban or agricultural sources of pollution). This may be complemented by a water-quality approach based on the establishment and compliance to water-quality standards, and the requirement to identify and reverse any statistically and environmentally significant pollution trends. There is no universally best approach, i.e. each situation may require tailor-made solutions which will be designed according to factors such as the urgency of pollution problems, the substance concerned, the pollution source and the capacity of the managers. In practice, the different approaches are often combined, e.g. minimum uniform emission standards combined with more stringent pollution controls if the water quality so requires.

### 8.4.2 Voluntary Agreements

Enforcement is a great concern in all regulatory instruments. Personnel and equipment are often insufficient for frequent monitoring, sometimes the different bodies responsible for enforcement may not co-operate effectively and political forces and lobbying may prevent strict sanctioning. Voluntary agreements and other communicative instruments may offer a partial solution, in particular with regard to agricultural activities. They are based on the co-operation of the (ground) water users or polluters: the latter are not forced but persuaded to do (or not to do) something. In this context, users and polluters may be willing to agree on quite ambitious goals, which may go beyond traditional regulatory incentives. This concerns not only groundwater regulations but also parent regulations (e.g. agriculture-related policies) directives which have to be effectively implemented to ensure a proper groundwater management planning.

### 8.4.3 Cost Recovery

Another operational issue is related to recovery of costs of water services, which takes into account that the polluter pays principle. It may require (like in the EU) authorities to establish water pricing policies, fixing adequate contributions of the different water uses, disaggregated into industry, households and agriculture. This policy depends on the price elasticity (the sensitivity of water use/pollution to the costs of the user/polluter), which is generally low in the case of drinking water use and high in the case of irrigated agriculture (the major water user in many countries). Charges that reflect the full economic and environmental costs of water use and pollution are economically efficient since they confront the water user/polluter with the real costs and promote an integral assessment of the costs and benefits. Moreover, they solve the financing problems of the providers of the water service concerned. However, this principle has to consider social, environmental and economic effects, as well as geographic and climatic conditions of the region or regions affected. In many instances, the cost recovery principle is not fully operational. An alternative approach is to fund particular preventive or remedial measures. This approach may be used, for example, if water becomes too expensive for poor populations. Indeed, very high charges and especially rapid increases may decrease the willingness to pay and may result in massive political opposition.

### 8.4.4 Institutional Structure

Mostert et al. (1999) illustrate different instruments for operational management that are applied in an institutional structure which consists of formal and informal working rules. Operational rules provide a framework for operational management, e.g. emission standards and (groundwater) policies. Collective choice rules deal with how operational rules should be developed, e.g. permitting and planning procedures. Constitutional rules determine who is entitled to make collective choice rules, setting up the organizational structure for RBM and allocate tasks and competencies (e.g. river basin district authorities). In this context, three basic RBM models are distinguished:

- The *hydrological model* in which the organizational structure for water management is based on hydrological boundaries. In its extreme form all water management is in the hands of a single entity: the "river basin authority".
- The *administrative model* is in many respects the opposite of the hydrological model. In this model water management is the responsibility of provinces, municipalities and other bodies not based on hydrological boundaries.
- The *coordinated model* falls somewhere between the hydrological and the administrative model. In this model water management is not performed by river basin authorities, but public agencies, public coordination bodies or public-private partnerships or private river basin organisations coordinate river basin management.

Each model has advantages and disadvantages. In the hydrological model, administrative procedures coincide with hydrological boundaries, which limit the risk of upstream–downstream conflicts. However, since river basin authorities usually deal with water management only, this model may isolate water management from other relevant policy sectors, and inter-sectorial coordination may become a problem. In the administrative model water management, land-use planning and other relevant policy sectors can be kept together (but not necessarily). A major disadvantage is the serious risk of upstream–downstream conflicts and the lack of a platform to discuss these problems. Finally, an example of coordinated model is illustrated by river basin commissions (e.g. the International Commission for the Protection of the Danube River). The different bodies participating in these commissions may individually ensure co-ordination between water management and other policy sectors, and together, in the commission, they may coordinate their water management.

## 8.5 Planning

Whereas operational RBM constitutes the functional core of RBM, planning linked to policies has an important supportive role to play. As important as the plans and policies themselves is the way in which they are prepared: the "planning process" is a means to improve and support operational management.

### 8.5.1 Functions of Plans and Policies

Plans and policies can support operational RBM in several ways. Firstly, planning helps to assess the present situation in the basin, starting by an analysis of pressures and impacts and economic considerations, and measures required to meet predefined targets (e.g. quality and quantity objectives). It helps to orient operational management and set priorities. Secondly, it is impossible in practice to carry out policy analysis and organize public participation for each individual operational decision, and planning may provide the necessary framework. Thirdly, open and participatory planning processes may result in more public support or acceptance of the resulting plan/policy and (by extension) operational management. Fourthly, plans and planning may have a coordinating effect, i.e. bringing different river basin managers into discussion with each other with resulting plans and policies acting as common focal points.

### 8.5.2 The Planning Process

Planning requires extensive technical and scientific information, preparatory work and negotiation, considering different steps as described by Mostert et al. (1999):

1. Identification of planning needs, possibly involving some preliminary research;
2. Analysis of the institutional RBM framework and identification of the different operational decisions that can be taken, the bodies responsible for these decisions and their management capacity;
3. Identification of all the possible other stakeholders and their main interests;
4. Preparation of a process design, describing the scope of the planning exercise; the different phases; the different groups to be involved in each phase and the means to do so; the necessary research in each phase; and the project organization;
5. Implementation of the process design, resulting in the adoption of a plan; and
6. Implementation of the plan.

After a while, the plan and its implementation can be evaluated, and the process can start again. This form of planning cycle with review taking into account scientific progress is in force within the EU Water Framework Directive (see Sect. 8.9).

### 8.5.3 Planning Systems

Plans and policies relevant to RBM can differ on many dimensions—policy sectors, geographical scope, available funding, etc.—which differ from country to country and from basin to basin. General guidelines may however be given, e.g. river basin planning should consider different interrelations within water systems (surface water and groundwater quantity and quality), the basin characteristics and their socioeconomic environment. This does not mean that each individual plan should have such a broad scope. Rather, the thinking should be in terms of planning systems: sets of interrelated types of planning, consisting of strategic and operational plans (e.g. linked to different regulatory frameworks concerning industrial, urban or agricultural activities). The more strategic a plan is, the more important it is that it covers complete river basins and all relevant policy sectors. Operational plans go more into detail and usually cover only one policy sector or part of a sector.

The types of plans will depend on specific features, e.g. if in a specific basin there is one very urgent, very obvious issue, such as pollution of drinking water sources, there may be no need for integrated strategic planning that provides a complete integrated description of the basin and sets long-term goals. The resources could be much better used for making and implementing an operational plan that sets specific and concrete targets, proposes operational measures, and creates the necessary support linked to the specific feature.

Generally speaking, plans should be designed, taking into consideration the management capacity of the countries and basins. The number and scope of plans may be constrained by the amount of resources available for each planning exercise. Coordination between the plans can become problematic and transparency for the citizen is reduced. Moreover, resources that are spent on planning cannot be spent on operational management.

## 8.6 Analytical Support

River basin management is a complex task. Therefore, tools helping to assess the present situation and assist the development and evaluation of solutions are important. Two types of support may be distinguished: (1) support to operational management (e.g. action programs) and (2) support to strategic policy-making and planning (e.g. RBPM cycles). A second distinction is between (support) systems for monitoring, data collection and processing, oriented towards making facts and figures about the present situation and about possible trends; and tools or systems to support decision-making with a view to the future, typically oriented to the *ex ante* identification, analysis and evaluation of alternative allocations, policies or plans. These distinctions are not absolute. Operational management and strategic policy-making interact, and data collection and *ex ante* analysis support each other.

The development of information and computer technology over the last 30 years has enabled the design and application of a wide array of systems and modeling tools for supporting water managers. Most efforts in the field have so far concentrated on the technical and physical aspects of the (physical) river systems itself, and little attention has been paid to the development of systems and tools covering relevant aspects and processes in the river basin as a whole. This can be partly explained by the complexity of monitoring and analyzing of the interaction between natural and socioeconomic systems at the scale of a river basin, which are informed by on-going research trends and development of multidisciplinary synergies.

### 8.6.1 Analytical Support for Operational Management: Main Challenges

Many analytical tools have become available to support operational management. With respect to groundwater, efforts are still required to harmonize monitoring and analysis methods used by different organizations, especially in the case of international basins. A second challenge is to make the information available to anybody involved or interested. The development in database technology, often in combination with internet applications, can provide powerful tools for data retrieval and map visualization.

A more advanced type of operational support is to combine on-line monitoring with computer models in order to predict future conditions of the system. Examples are early warning systems, both for water-quantity issues (floods, droughts) and for water-quality issues (accidental spills). Flood early warning systems are already installed in many major basins in the world. An even more advanced form of support is the automation of infrastructure operation, such as weirs, pumps and sluices. In most cases such tools do not replace human operators: they provide the necessary information, but the decision is left to operators. This information is generated using monitoring data, often combined with computer models that describe the behavior of the natural system (water levels, discharges, etc.). The main challenge is to develop support systems that describe not only the natural system but also the use functions related to this system, thus enabling a weighing of all aspects involved.

### 8.6.2 Analytical Support and the Strategic Level: New Directions

At the level of strategic planning and policy-making, efforts so far are mainly related to the development of specific tools for specific problems in specific river basins, e.g. options for managing and cleaning up heavy metal pollution in a given groundwater body. Challenges for developing more generic and comprehensive tools at the river basin level are enormous as there is a lack of data and theories that may fully describe complex processes taking place in a groundwater body or groups of groundwater bodies within a river basin, taking socioeconomic issues into consideration. This does not allow one to include all relevant issues in a single model or tool. Yet, given the crucial importance and complexity of management at the basin level, it is of utmost importance that investments are made in the further development of analytical approaches and associated tools. Some possible tool development orientations are highlighted by Mostert et al. (1999):

- Tools for supporting integrated management and analyses at the river basin level describing not only the different aspects (quantity and quality) of the physical system, but also interactions with the socioeconomic system;
- Tools facilitating the linkage of (aggregated) strategies at the basin level and strategies at the regional and local levels to take account of processes and implementation aspects that have a regional rather than a basin-wide character. The challenge is to develop a family of tools operating at different geographical scales and levels of aggregation, linked to each other for overall consistency;
- Tools or models describing the costs and benefits of specific actions to the various actors involved, also helping to explore the possibilities for exchanges

between actors, to assess the need to involve other actors in the process and possibly to identify potential linkages to other issues that would turn in a win–lose situation into a win–win situation. Analysis of cost and benefits need to take account of recent developments in the estimation of unpriced values, especially environmental valuation;

- Support systems and tools that are better tuned to the dynamic and increasingly participatory nature of policy processes, i.e. accessible to non-specialists. For interactive learning settings there is a need for more flexible and transparent tools;
- Alternatives to the traditional tools based on "objective" system analytical approaches should be explored, e.g. striving to distinguish between "objective" knowledge and subjective judgments. Perceptions of problems and solutions are inevitably affected by differences in interests of participants, and arguments put forward in policy debates typically contain a mixture of "objective" facts and subjective viewpoints or perceptions. Argumentation analysis may be supported by tools specifically designed to describe, visualize and analyze policy arguments;
- Another novel approach is to use gaming as a vehicle for learning. In a policy game, participants interact as if they were playing the role of different parties involved in a real-world issue. Such games can be very instructive to both participants and observers as they include parts of the social and psychological dynamics of real policy processes, which cannot be included in more traditional systems. Policy games are generally supported by computer-based tools that take account of physical and other aspects in the process;
- New opportunities linked to developments of information and communication technology, e.g. geographical information systems (GIS) and interactive interfaces, allowing use of support tools by a broader group of users, and the development of the internet.

## 8.7 Internationally Shared Aquifers

A special management feature concerns internationally-shared aquifers. Natural and socioeconomic conditions, culture and language often differ significantly between different parts of the region where the aquifer is located, and consequently upstream–downstream conflicts may occur. More importantly, however, internationally shared aquifers are by definition located in different states. Consequently, international co-operation is needed in order to best manage the aquifer resources. This co-operation can be made more effective when required by law. In this respect, a major problem in the management of international basins is the so-called "lowest common denominator": Few obligations can be imposed on countries without their own consent in the absence of an international regulatory framework imposing coordination towards the achievement of common objectives. In the absence of such international law, many international agreements simply reflect the commonalities in the national policies of the states concerned or are very procedural and vague.

At the global level the normative system for the management of internationally shared aquifers focuses on the discretion of states and their sovereignty, rather than on their particular responsibilities in the process towards attaining sustainable water management, even if cooperation among those states is encouraged in conformity with existing agreements. Compliance regimes have now been included or are being developed in most multilateral environmental agreements, e.g. a procedure that entails that, at the request of a state, the commission coordinates negotiations among the parties and makes recommendations for an equitable solution to the dispute. While these recommendations are not binding in law, the parties to the dispute are to consider them in good faith. Such a procedure remains short of the compliance regimes included in multilateral environmental agreements in that it does not provide an automatic peer review system. It may, however, provide a mechanism through which the normative content of the international regime for groundwater management may be enhanced.

## 8.8 Public Participation

Public participation plays an essential role in planning and policy-making. It can be seen as a legal right of individuals and social groups, often resulting in procedural requirements for decision-making. Public participation can also be seen as a means for empowering individuals and groups and developing local communities. Furthermore it can be seen as a means of improving the quality and effectiveness of decision-making (REF). Public participation as a legal right is based on the notion that individuals and groups affected by decisions should have the opportunity to express their views and become involved in decision-making. Often three “pillars” of public participation are identified: access to information, involvement in the decision-making process (e.g. possibility to comment), and access to justice (right of legal review and redress). The danger of a purely legal approach to public participation is that it may become nothing more than an administrative requirement. Moreover, litigation is often time-consuming and expensive.

With regard to groundwater management, four groups stand out and should, as a basic principle, be involved in management initiatives:

- local stakeholders—water users and others whose interests are directly affected by groundwater management and whose actions often determine the effectiveness of any given initiative;
- policy-makers—those who have the ability to influence the institutional environment within which management approaches must evolve;
- public-sector organisations—these stakeholders often have their own internal agendas and control large programmes that either directly or indirectly have major impacts on water resources; and

- private-sector organisations—these stakeholders are often major water users whose interests may or may not coincide with those of local stakeholders.

Stakeholder involvement and education are essential for any attempt to manage groundwater resources. It cannot, however, concern each individual but rather groups representing communities which may have a major impact on the resource (e.g. large water users such as municipalities, agricultural sector) and those whose interests will be significantly affected by management regimes (these groups are not mutually exclusive). The principle of stakeholder involvement is to start by being as inclusive as possible. The involvement and education will be all the more efficient if it is linked to a legal base, thus mixing stakeholder organisations with policy makers guiding discussions in relation to policy development, implementation and review needs.

## 8.9 The EU Approach

Groundwater planning within the EU regulatory context derives directly from the components of the Water Framework Directive, covering the following steps:

- Definition and characterisation of groundwater bodies (management units) within well-defined River Basin District which had to be carried out in the years 2004–2005. This involved an analysis of the pressures and impacts of human activity on the quality of groundwater with a view to identifying groundwater bodies at risk of not achieving WFD environmental objectives (of "good status", see below). This assessment has to evaluate risks linked to water uses and interactions with associated aquatic or terrestrial ecosystems in relation to the types of pressures and aquifer vulnerability;
- Establishment of registers of protected areas within each river basin district, which have been designated as requiring specific protection of their surface and ground waters or for the conservation of habitats and species directly dependent on water;
- Design and establishment of groundwater monitoring networks based on the results of characterisation and risk assessment to provide a comprehensive overview of groundwater chemical and quantitative status (this had to be done by EU Member States by the end of 2006). In this context, data monitoring constitutes an essential element of the overall management cycle;
- Development of river basin management plan (RBMP) for each river basin district, including a summary of pressures and impacts of human activity on groundwater status, a presentation in map form of monitoring results, a summary of the economic analysis of water use, as well as the implementation of the principle of recovery of costs for water services, including environmental and resource costs in accordance with the polluter pays principle, a summary of protection programmes, and control and remediation measures. The first RBPM

has been published in December 2009. A review is then planned by the end of 2015 and every 6 years thereafter;

- Development and implementation of a programme of measures for achieving WFD environmental objectives (e.g. abstraction control, prevent or control pollution measures) operational since 2012. Basic measures include, in particular, controls of groundwater abstraction, controls (with prior authorisation) of artificial recharge or expansion of groundwater bodies (providing that it does not compromise the achievement of environmental objectives, meaning that the reuse of e.g. treated wastewater should not lead to a deterioration of the quality of receiving ground waters). Point source discharges and diffuse sources liable to cause pollution are also regulated under basic measures which are in force in other directives e.g. agriculture-related directives (Nitrates, Plant Protection Products), urban-related directives (Urban Wastewater Treatment) or chemical industry-related directives (Integrated Pollution Prevention and Control). Direct discharges of pollutants into groundwater are prohibited subject to a range of provisions listed in Article 11 of the WFD. The programme of measures has to be reviewed and if necessary updated by 2015 and every 6 years thereafter.

The Groundwater Directive (GWD) complements the above WFD components in establishing a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater (European Commission 2006). The directive establishes quality criteria that take into account local characteristics and allows for further improvements to be made based on monitoring data and new scientific knowledge. It thus represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive (WFD) as it relates to assessments on chemical status of groundwater and the identification and reversal of significant and sustained upward trends in pollutant concentrations. In this context, EU Member States had to establish the standards (threshold values) at the most appropriate level, taking into account local or regional conditions. Complementing the WFD, the Groundwater Directive includes the following obligations:

- groundwater threshold values (quality standards) had to be established by Member States by the end of 2008 and revised on a regular basis in the light of scientific knowledge;
- pollution trend studies should be carried out using existing data and monitoring data which are mandatory under the WFD (referred to as "baseline level" data obtained in 2007–2008);
- pollution trends should be reversed so that environmental objectives are achieved by 2015 using the measures set out in the WFD (corresponding to a series of parent legislation setting legal rules for agricultural, domestic and industrial pollution risks and management);
- measures to prevent or limit inputs of pollutants into groundwater should be operational so that WFD environmental objectives can be achieved by 2015;

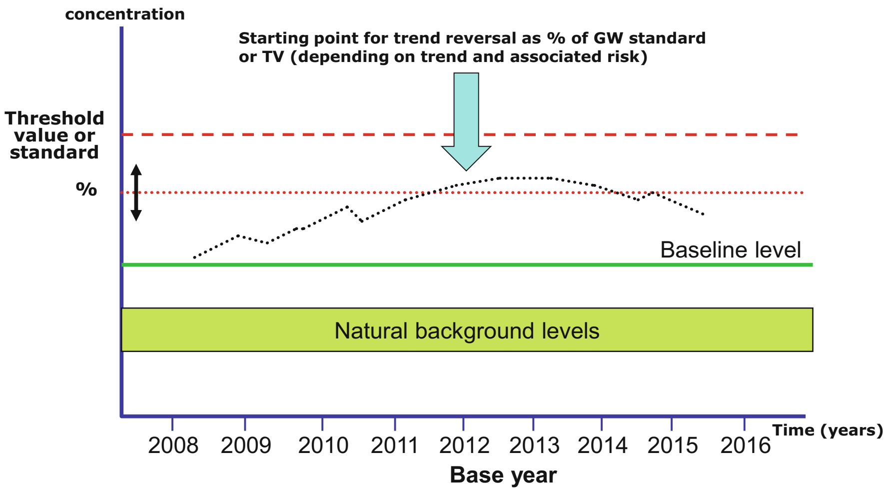


**Fig. 8.1** Principle of the identification and reversal of statistically and environmentally significant upward trends. The 'Baseline Level' corresponds to the average value measured at least during the reference years 2007 and 2008 on the basis of monitoring programmes of the WFD, while the 'Background Level' means the concentration of a substance of the value of an indicator in groundwater corresponding to no, or only very minor, anthropogenic alterations to undisturbed conditions. TV stands for 'Threshold Values'

- compliance with good chemical status criteria (based on EU standards of nitrates and pesticides and on threshold values established by Member States) should be achieved by the end of 2015.

The good chemical status achievement is based on quality objectives (compliance to relevant standards either EU-based or established by the Member States, no saline intrusion) that have to be achieved by the end of 2015. The identification of sustained upward pollution trends and their reversal implies that trends will have to be identified for any pollutants characterising groundwater as being at risk (this is linked to the analysis of pressures and impacts carried out under the WFD). The reversal obligation establishes that any significant and sustained upward trend will in principle have to be reversed when reaching 75 % of the values of EU-wide groundwater quality standards and/or threshold values (Fig. 8.1) through the programme of measures of the WFD where the parent legislations are the implementation tools for ensuring effective actions (e.g. Nitrates Directive, IPPC Directive, etc.).

Finally, measures to prevent or limit the introduction of pollutants into groundwater are related to the level of risks of different types of substances (some to be prevented, others to be limited). The principles are linked to conceptual modelling needs (Fig. 8.2).

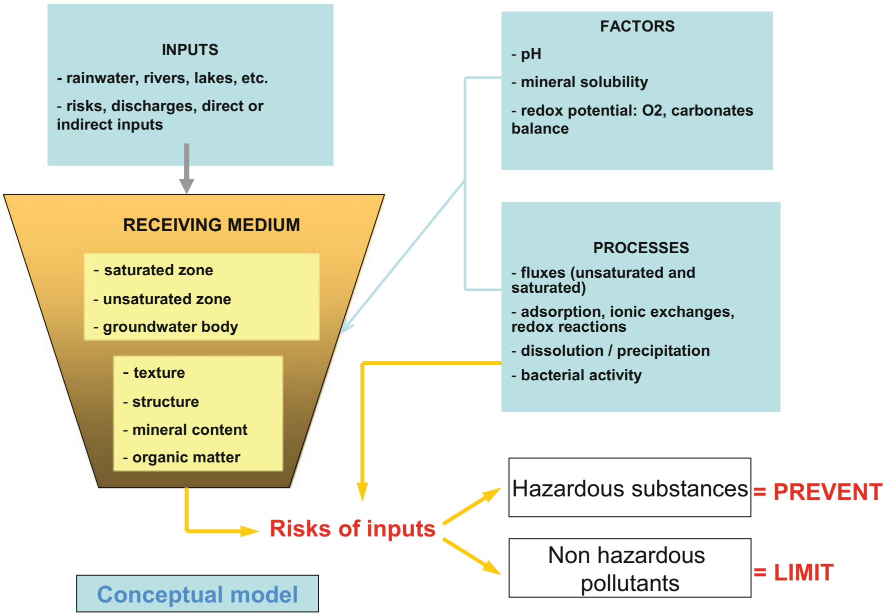


**Fig. 8.2** The "Prevent and Limit" provisions linked to an evaluation of risks of inputs (and of the understanding of the groundwater system)

## 8.10 An Example from Michigan, USA: A State Level Approach

In contrast to an EU-scale approach, this section describes a statewide innovative management model for considering the ecological impact of groundwater and surface water withdrawals. The approach is notable for its focus on science-based tools and involvement from a range of stakeholders in the State of Michigan. The reader is directed to Steinman et al. (2011), and citations contained therein, for detailed coverage of the historical aspects and processes employed; Hamilton and Seelbach (2011) provide a comprehensive description of the withdrawal assessment process and Internet screen tool.

Groundwater management within the Michigan regulatory context derives directly from a series of governing laws, including:

- Definition and characterisation of groundwater bodies (management units) within well-were initially defined on an international scale. In 2001 and 2005, the governors and premiers of all United State Great Lakes states and Canadian provinces, respectively, committed to developing a progressive water management system to protect the waters of the Great Lakes basin. In 2005, the governors and premiers signed the "Annex 2001 Implementing Agreements" which banned diversions of water outside the Great Lakes (with limited exceptions). The Annex consisted of a good faith agreement between all parties, and a binding Compact among the eight US Great Lakes States. As a result, Great Lakes region has an overarching common regulatory framework, which is enforceable against the interstate movement of Great Lakes water due to its being ratified by the federal government;

- The Compact allows flexibility in each state's approach to implementation. A common, resource-based conservation standard applies to new or increased large-quantity (over 265 litres per minute (100,000 gallons per day)) water withdrawals from the Great Lakes basin. The intent of the standard is to avoid significant adverse individual or cumulative impacts on the quantity and quality of the waters and water-dependent natural resources of the Great Lakes basin;
- The states and provinces are also required to: establish programs to manage and regulate new or increased withdrawals; implement mechanisms for decision making and dispute resolution; develop an assessment approach for individual and cumulative impacts of water withdrawals; and augment scientific information in the Great Lakes basin and the impacts of the withdrawals on the ecosystems;
- To execute their responsibilities of the 2001 Annex agreement, the Michigan legislature passed Public Act 148 in 2003. The law's language formed the Groundwater Conservation Advisory Council and placed it within the Michigan Department of Environmental Quality (MDEQ), and explicitly denoted that its membership would consist of ten voting members from water using stakeholders and three non-voting (state agency) members. Public Act 148 also mandated a groundwater inventory and mapping effort.
- Initially, the 2003 Council was charged to: (1) study statewide sustainability and assess the need for additional oversight over groundwater withdrawals; (2) assess the state's implementation and statutory conformance with Annex 2001 requirements; and (3) assess the implementation and results from a dispute resolution program. The Council was given 2.5 years to submit a final report to the Michigan Legislature.
- After receiving the Council's final report, the Michigan Legislature enacted Public Act 34, legislation in 2006, legislation that for the first time regulated water withdrawals in the state and explicitly mandated that science should be used as the basis for decision making—a specific requirement of the overarching Compact. The 2006 law reconstituted the Council, which was then tasked to develop explicit criteria for judging sustainability, and to develop and design a water withdrawal assessment tool.

*Criteria for Assessing Sustainability* Efforts focused on development of characteristics of sustainability criteria and indicators. Criteria were defined as standards or points of reference that help in choosing indicators; they are more general and less detailed than indicators. Indicators were defined as measures that present relevant information on trends in a readily understandable way. Good indicators were defined as those that adequately represent the societal concern, be measurable, consistent, based on readily available or obtainable information, and comparable among various geographic regions (Steinman et al. 2011). Eleven indicators were identified (Table 8.1). Five environmental indicators focused on water quantity and quality. An indicator of the impacts of water withdrawal on groundwater-dependent biota was not developed because the state of the science was not sufficient to adequately relate the effect of withdrawals on these biota. Consensus was reached on three general economic indicators (Table 8.1), after considerable debate; three social sector indicators were identified (Table 8.1) that focused on public education, conservation and restricted groundwater access.

*Development of a Water Withdrawal Assessment Tool* The purpose of the water withdrawal assessment tool is to assist a large quantity user (threshold of 265 litres per minute/100,000 gallons per day defined using the Great Lakes Compact language) or the state discern if a proposed withdrawal is likely to cause an Adverse Resource Impact (ARI). An ARI is characterized in terms of an ecological functional impairment and defined by whether or not a water withdrawal impairs the ability of a surface-water body to support characteristic fish populations. Thus, fishery health was used as a biological proxy for overall stream functional integrity. The final water withdrawal assessment process provides outputs on two levels: (1) a screening tool, that is designed to 'screen in' (that is, to say yes to) those proposed withdrawals that are highly certain not to cause an ARI; and (2) for those withdrawals not initially 'screened in'. The applicant has a choice: they may either change the size, location, or depth of the proposed withdrawal in order to attain a 'screen in' decision or, if their application cannot pass using the tool, they may request the MDEQ to undertake a site-specific review. The applicant can provide site-specific measurements to assist with this review, but the expectation was that the review can be performed using readily available information.

The Internet-based (on-line) water withdrawal assessment tool comprises three models linked through a GIS. The models use information about streamflow, groundwater withdrawal and existing fish communities, with detailed resolution that allows site specific assessments of stream segments across Michigan. The streamflow model is a regression model that describes how much flow is in Michigan streams. An index flow is calculated from online data obtained from 147 established stream gages. Index flow is defined as the median flow for the summer month with lowest flow at a site. Summer months (usually August or September) were used because they commonly have the lowest flows and warmest temperatures, which result in the greatest stress to fisheries. A subsequent analytical withdrawal model estimates how much a proposed groundwater withdrawal will reduce streamflow in streams near the proposed pumping location. This model takes into account the amount and duration of pumping, well depth distance of well from stream, and aquifer properties (Reeves et al. 2009). The withdrawal assessment tool can also account for direct surface water withdrawal by subtracting it from the amount of available water.

The most critical component is the third model, a fish community statistical model that relates reduced streamflow to fish populations. This model leverages a

**Table 8.1** Recommended groundwater sustainability indicators and their associated measurement and criteria for the environmental economic and social sectors (Taken from Steinman et al. 2011)

| Indicator | Measurement | Criteria |
|---|---|---|
| *Environmental sector* | | |
| 1. Groundwater contribution to stream baseflow | 1-1. Change in groundwater contribution over time | 1-1. Adequate groundwater discharge to maintain natural flow and temperature regimes |
| 2. Groundwater withdrawals | 2-1. Volume of water use by sector | 2-1. Efficient use to maintain adequate supply for public and private needs |
| 3. Land use/land cover | 3-1 Percentage natural land use/land cover | 3-1. Increase |
| | 3-2. Percentage impervious surface | 3-2. Decrease below reference impairment thresholds |
| 4. Groundwater contamination | 4-1. Number of at-risk sites | 4-1. Decrease |
| 5. Groundwater-dependent natural communities | *Not developed* | *Not developed* |
| *Economic sector* | | |
| 6. Cost of groundwater by relevant economic sector | *Not developed* | *Not developed* |
| 7. Groundwater dependent commerce | 7-1. Product-revenue per unit groundwater per sector | 7-1. Increase |
| | 7-2. Efficiency of groundwater use per sector | 7-2. Increase |
| 8. Water usage from alternative sources | 8-1. Gallons of water recycled | 8-1. Increase |
| | 8-2. Gallons of water used from collection of stormwater | 8-2. Increase |
| *Social sector* | | |
| 9. Public education | 9-1. Public knowledge of groundwater resources | 9-1. Increase |
| | 9-2. Water resource education | 9-2. Increase |
| | 9-3. Local government training | 9-3. Increase |
| 10. Conservation | 10-1 Public water systems using groundwater | 10-1. Efficient use to maintain adequate supply for public and private needs |
| | 10-2 Water utilization by sector | 10-2. Unspecified |
| 11. Restricted groundwater access | 11-1. Use restrictions due to contamination | 11-1. Decrease |
| | 11-2. Adverse Resource Impacts (ARIs) | 11-2. Decrease |
| | 11-3. Water use conflicts | 11-3. Decrease |

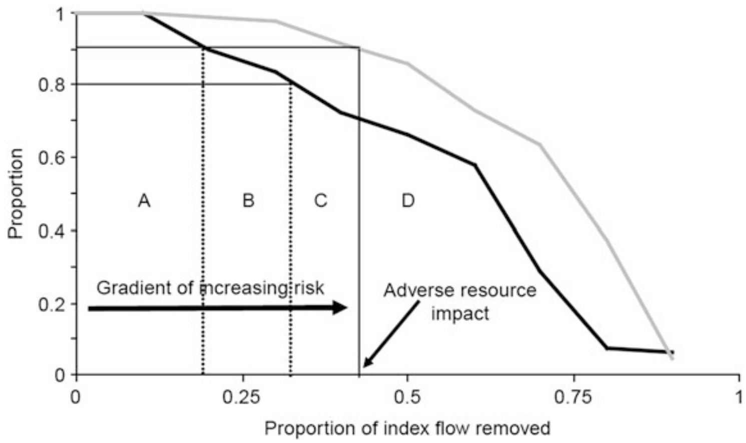


**Fig. 8.3** Hypothetical example showing four policy zones (A–D), demarcated by increasing levels of index flow removal and functional response of fish populations (proportion of populations). The *black curve* represents the response of those fish whose needs are best suited to the stream temperature and flows. The *gray line* represents the response of more tolerant fish that require similar stream temperature and flows but are not as tied to the conditions as those represented by the *dark line* (From Steinman et al. 2011, used with permission)

large Michigan Department of Natural Resource's dataset of fish abundance at around 1700 stream locations in Michigan. Fish abundance is related to 11 river classes in Michigan, based on temperature type (cold, cold-transitional, cool, and warm) and size (large rivers, small rivers, and streams). This model estimates, for each of the 11 stream classes, the change in fish populations caused by reducing streamflow by using characteristic response curves.

Two curves were generated for each of the 11 stream classes in Michigan; these curves show how fish population responds as flow is incrementally reduced (Fig. 8.3). The leftmost curve shows the response of thriving species (fish best suited for stream conditions) and a rightmost curve that shows abundance reductions of other fish that more general and less dependent on the stream condition environmental niche (Zorn et al. 2008). This curve was divided using stakeholder and scientist input, and resulted in three vertical lines and four corresponding zones (A–D—Fig. 8.3). The far left vertical line (demarcating zones A and B) showed the theoretical edge of minor impact, whereas the far right vertical line showed the theoretical start of an ARI (Fig. 8.3). That is, Zone A represents minimal measurable impact on fish populations, but as more flow is removed, there is a gradient of increasing risk to the point where notable replacement of fish species occurs, thereby constituting an ARI (Fig. 8.3).

According to 2006 Public Act 34, a person considering a new or increased large quantity withdrawal is not allowed to cause an ARI. A proposed user may either start the application process on-line by using the screening tool or they may work directly with MDEQ staff to conduct a site-specific analysis (Fig. 8.4). The screening tool estimates the amount of flow reduction for the appropriate stream segment

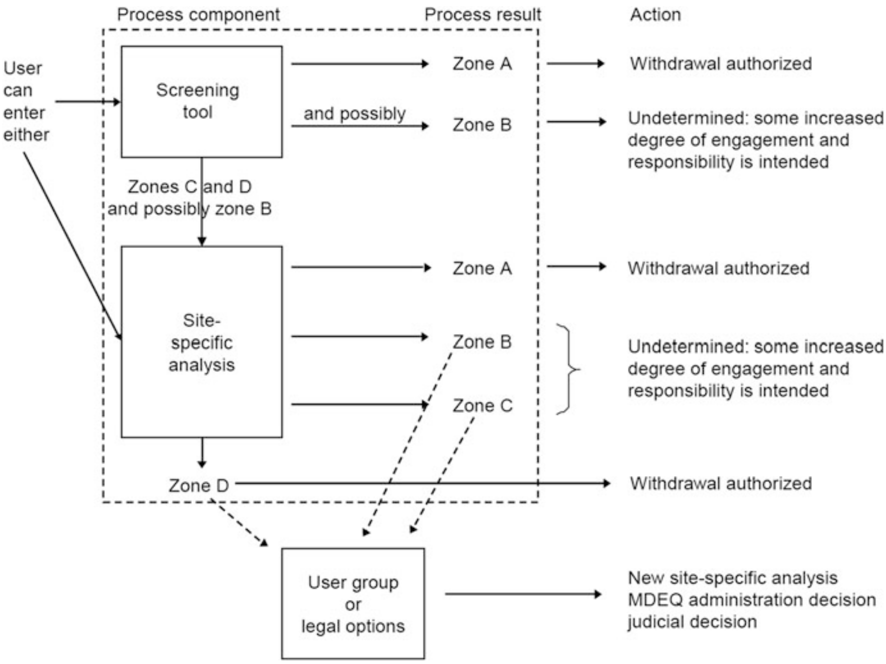


**Fig. 8.4** Decision-making system associated with the water withdrawal process. Zones listed under process results correspond to Fig. 8.3 (From Steinman et al. 2011, used with permission)

and makes one of two determinations for the proposed withdrawal: (1) that it is not likely to cause an ARI and is authorized; or (2) that there is too much uncertainty in the outcome to determine whether or not the withdrawal would be likely to cause an ARI, and therefore the withdrawal may not proceed without a site-specific review. For a Zone A determination (ARI not likely; Figs. 8.3 and 8.4), the user would simply register the proposed withdrawal with MDEQ and receive authorization to proceed. For Zones B and C determination (ARI possible; Figs. 8.3 and 8.4), the applicant can modify the proposal and try the screening tool again or they can request the MDEQ to conduct a site-specific analysis of the withdrawal, with the expectation that a site-specific analysis will have less uncertainty associated with the withdrawal estimate than the screening tool. As of 9 July 2009, use of the screening tool is required by individuals proposing a large quantity withdrawal (265 litres per minute/100,000 gallons per day) from the groundwaters of Michigan. However, the Council recognized that the water withdrawal assessment tool is a work in progress (Steinman et al. 2011), specifically with the proposed the boundaries of Zones A and D (Fig. 8.3). They suggested that these were the starting points for further policy discussion, and recognizing that the social values of affected constituencies ultimately would influence the location of the boundaries. Indeed, the 2008 implementing legislation contained significant negotiated changes in the location of the Zone A and D lines for most of the 11 stream classifications (Steinman et al. 2011).

A new group, the Michigan Water Resources Conservation Advisory Council, was created as part of legislation passed in 2008. This group extends the earlier work but has a broader membership, and is charged with evaluating all water resources in the state, not just groundwater. Specifically, the new council is charged with: (1) evaluation of the water withdrawal assessment tool; (2) evaluation of the overall water withdrawal assessment process; (3) recommendations for inclusion of Great Lakes, inland lakes, and other waters in the process; (4) examining any potential legal conflicts within the process; and (5) recommendations for a new state water conservation and efficiency program (Steinman et al. 2011).

## 8.11 The Australian Approach

In comparison to the EU and US examples, this section reviews the background, past and current issues in groundwater regulation and integrated water planning for Australia.

### 8.11.1 Early Approach

In Australia water management has been dominated during most of the first 200 years of settlement by providing sufficient water for the growing population, agriculture and industry, hence aiming at increasing the exploitation of water. As Australia has high rainfall variability and is the driest continent on earth, exploitation of water resources has always been strongly linked to irrigation as it is the biggest water user (CSIRO 2011).

Irrigation started in 1886 in Mildura on the banks of the Murray River drawing on expertise from irrigation schemes in California to Victoria. Ownership of water and the rights to water use was setup according the model established by the Victorian Irrigation Act of 1886 and translated into State legislative arrangements. The legislation followed the principle that all streams were public property, and vested in the State or Crown the right to the use and flow, and to the control of water in any watercourse. Ownership and right of use of groundwater arose subsequently to that of surface water and hence the property in and the rights to the use, flow and control of all groundwater was vested in the Crown since 1910 by the different States, starting with Queensland (Acworth et al. 2009).

### 8.11.2 The Murray–Darling Basin

The Murray–Darling Basin covers more than 1 million $km^2$ and spans most of the states of New South Wales, Victoria, and the Australian Capital Territory, and parts of the states of Queensland and South Australia. Agriculturally it is essential for the food production of Australia, while the management of irrigation in the basin has a long history and is still a politically sensitive issue. A drought period (1895–1902) and the Federation of Australia (1901) drove the government to start managing and regulating the Murray River system. The upstream states, Victoria and New South Wales, favoured the riparian doctrine, under which landowners are free to take water from streams flowing through their property. South Australia relied on agreements in the new Constitution on navigation along the Murray River to preserve flows in the South Australian section of the river (Wikipedia Contributors 2013).

The River Murray Waters Agreement (1915) did set out how flow and control is shared between New South Wales and Victoria and how South Australia is guaranteed of a minimum quantity of water or “entitlement”. The agreement was also the starting point for construction of dams, weirs and locks on the main stream of the Murray to be managed by the River Murray Commission, which was established in 1917. As water is a state authority this agreement was an early example of federal cooperation on water, although limited to the management of water for irrigation and navigation (Wikipedia Contributors 2013).

As over the decades environmental problems due to overallocation of water for irrigation become seriously felt, the need for more coordination at the Basin level became evident. Updated and new versions of the Murray–Darling Basin Agreement were signed in respectively 1987 and 1992. The stated purpose of the Murray–Darling Basin Agreement was ‘to promote and coordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray–Darling Basin’. To support the new Agreement, institutions at the political, bureaucratic and community levels were established, respectively (Wikipedia Contributors 2013):

- Murray–Darling Basin Ministerial Council;
- Murray–Darling Basin Commission; and
- Community Advisory Committee.

In 2012 finally after long negotiations the different Murray-Darling Basin states agreed on a new Murray-Darling Basin plan with as main result the promise to return 3200 gigalitres of environmental flows to the basin system annually, which is regarded essential to restore the strongly deteriorated health of the river’s floodplains, and important large RAMSAR and other wetlands. The basin plan foresees setting up strategies for environmental watering, trading and sustainable diversion limits. The plan further encompasses state water resources planning, revision and review steps of the plan (Fig. 8.5).

### 8.11.3 Groundwater Use

In 2013 the total water consumption in Australia is estimated to be about 15,000 GL per year. Approximately one third of this amount comes from groundwater, with

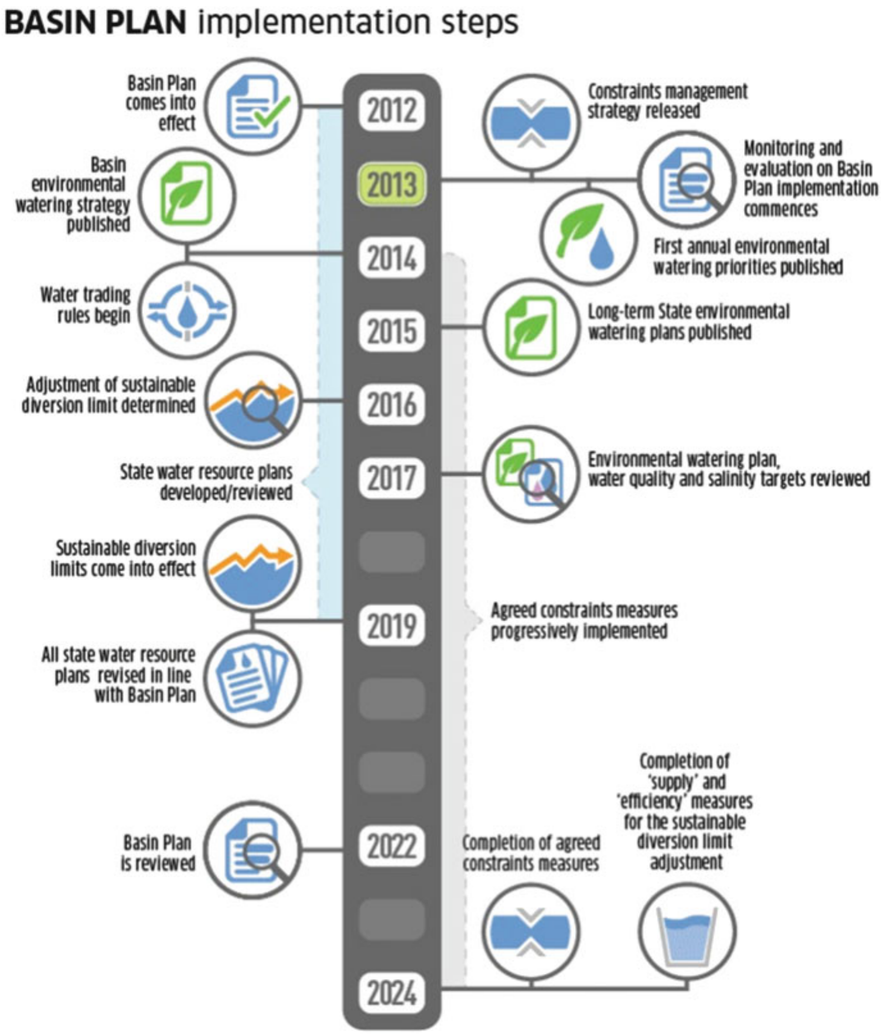


**Fig. 8.5** Murray-Darling Basin Plan implementation steps (Murray-Darling Basin Authority 2013)

use doubling between 1983/1984 and 1996/1997 (AWRA 2000). These values have a high uncertainty as only a small fraction of abstraction wells are metered. The highest use of groundwater is in the Murray-Darling Basin, where over 1700 GL of groundwater is abstracted annually in support of irrigated agriculture (NCGRT 2013; Murray-Darling Basin Authority 2010; CSIRO 2008).

The highest ratios of groundwater use to sustainable yield are found in Queensland (38 %), South Australia (33 %), New South Wales (26 %) and Western Australia (20 %). However, these statistics are misleading as they suggest scope for more groundwater extractions. While that is true in some areas, many major aquifers have been exploited up to or exceeding the sustainable yield, especially the Great Artesian Basin and alluvial aquifers of the Murray-Darling Basin. The lack of resource management and monitoring of groundwater systems have led to this overallocation and extraction, which was worsened by too little metering of groundwater extractions, provision of free or under-priced groundwater and not recognizing the importance of groundwater-surface water interaction (NWC 2013).

### 8.11.4 National Level Policy

#### 8.11.4.1 The National Water Initiative

In 2004 a National Water Initiative was started as a consequence of the fact that the Murray–Darling Basin Agreement did not result in significant improvement in the environmental conditions in the basin as well as because of the growing number of other water policy issues elsewhere in Australia (Wikipedia Contributors 2013). As part of the National Water Initiative a National Water Commission was established through an intergovernmental agreement (Council of Australian Governments). The Commission provides independent and public advice to the Council of Australian Governments and the Australian Government by assessing, auditing and monitoring water reform progress. The main policy agreement is the National Water Initiative, Australia's enduring blueprint for water reform. The National Water Initiative agreement included objectives, outcomes and agreed commitments to (NWC 2013):

- prepare water plans with provision for the environment
- deal with overallocated or stressed water systems
- introduce registers of water rights and standards for water accounting
- expand the trade in water
- improve pricing for water storage and delivery
- meet and manage urban water demands.

Full implementation of the National Water Initiative aims to deliver (NWC 2013):

- effective water planning: transparent and statutory-based water planning that deals with key issues such as the natural variability of water systems, major water interception activities, the interaction between surface water and groundwater systems, and the provision of water to achieve specific environmental outcomes.
- clear, nationally compatible and secure water access entitlements: providing more confidence for those investing in the water industry through more secure

water entitlements; better and more compatible registry arrangements; better monitoring, reporting and accounting; and improved public access to information.
- conjunctive management of surface water and groundwater resources: so that the connectivity between the two is recognised, and connected systems are managed in an integrated manner.
- resolution of overallocation and overuse: returning overallocated systems to sustainable levels of extraction as quickly as possible.
- clear assignment of the risks associated with changes in future water availability: ensuring that the risks arising from reductions in the pool of water available for consumptive use are shared between governments and water users according to an agreed framework, to provide investors and entitlement holders with certainty about how changes will be dealt with.
- effective water accounting: providing information on how much water there is, where it is, who has control of it, who is using it, and what it is being used for in order to support confidence about the amount of water being delivered, traded, extracted and managed for environmental and other public benefits.
- open water markets: removing artificial barriers to trading in water entitlements and allocations, bringing about more productive water use and enabling more cost-effective and flexible recovery of water to achieve economic, social and environmental objectives.
- effective structural adjustment ensuring that water policy, planning and management are facilitating and expediting adjustment, rather than impeding it.

Under the National Water Commission Act, the Commission has to report to the Council of Australian Governments on progress towards National Water Initiative objectives and outcomes. Reports were delivered in 2007, 2009 and 2011 and will further be delivered on a triennial basis (NWC 2013).

### 8.11.5 National Groundwater Action Plan

A National Groundwater Action Plan was initiated by the National Water Commission in 2007 as a consequence of the millennium drought (1997–2009). It had three elements (McKay 2012; NWC 2013):

- The National Groundwater Assessment Initiative: investigations to help overcome critical groundwater knowledge gaps.
- The National Centre for Groundwater Research and Training: a joint venture between the National Water Commission and Australian Research Council to build capacity in groundwater knowledge.
- A knowledge and capacity-building component: improvements in understanding and sustainable management of groundwater resources.

Within the National Groundwater Action Plan groundwater reforms and investments were foreseen in eight priority themes (McKay 2012; NWC 2013):

- Harmonization of groundwater definitions and standards, and improved governance and management practices.
- Northern Australia Groundwater Stocktake.
- National assessment of sites suitable for managed aquifer recharge and recovery.
- Vulnerability assessment of groundwater-dependent ecosystems.
- Investigation of groundwater–surface water interconnectivity.
- Strategic aquifer characterization to quantify sustainable yields.
- National review of groundwater potential for deep fresh, saline and brackish waters.
- Managing risks to groundwater quality.

### 8.11.6 Implementation of Policy at State and Local Levels

As the different States are also responsible for the management of groundwater each bases it on their own legislation and regulates it via water management agencies, department of water or natural resources management agencies. The formulation of Natural Resource Management legislation has brought the integrated management of natural resources under one management portfolio in some States (Acworth et al. 2009).

Groundwater in Australia is governed by state policies mostly implemented through local area plans. However, a considerable part of Australia is still managed at statewide level because of either the low level of development or because of the general poor quality of the groundwater resources. Allocation of groundwater occurs via a system of renewable water access entitlements. Allocation planning requires assessment of sustainability, which is defined by the National Water Initiative as 'the level of water extraction from a particular system that, if exceeded, would compromise key environmental assets, or ecosystem functions and the productive base of the resource'. A range of methods is used to estimate the sustainable yield often reflecting the state of the knowledge of particular hydrogeological systems (NLWRA 2001; Acworth et al. 2009; NCGRT 2013). Options for optimization of use are (Acworth et al. 2009):

- Fixed water allocations, where licences can use up to a fixed amount. Penalties can be applied if use exceeds allocations.
- Announced allocations, where allocations are varied, usually from 75 % to 125 % of the fixed allocation, depending on the volume in storage at the start of the main demand period.
- A system of advanced draws, where licensees can "borrow" against next year's allocation, with that year's allocation being reduced (a gamble on next year's wet season).

- A system of moving averages, whereby use is averaged with the two (or some other agreed number) preceding years, in order to average water use with the varying seasons.
- Temporary trading, where unused allocations can be transferred to other users, usually subject to some conditions. These transfers are usually private transactions, often financial, which must be sanctioned by the managing authorities.
- Permanent trading, where allocations can be sold permanently to others.
- Conjunctive allocations where groundwater and surface water allocations are tied.

### 8.11.7 Groundwater Quality

In terms of water quality the joint Australian-New Zealand National Water Quality Management Strategy of 1994 sets out the management process to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development (NWQMS 1994). As part of this National Water Quality Management Strategy the groundwater protection guideline details the principles for groundwater protection, which received comparably little attention over the decades. The protection framework involves the identification of specific beneficial uses and values for every major aquifer. Protection strategies include development of vulnerability maps, aquifer classification systems and wellhead protection plans, land-use planning measures and environmental management of modern waste management problems. All of these involve monitoring. Nearly all protection strategies will rely on government intervention, a public planning process and should be backed by community support (NWQMS 1995).

### 8.11.8 Challenging Contemporary Groundwater Management Issues

Australia faces currently and in the coming decades a number of highly challenging groundwater management issues. A robust policy framework is in place to address these, but it is likely that further adaptation and development of (ground)water policies will be required. Such issues include (Acworth et al. 2009; Tan et al. 2012; NCGRT 2013).

- Unsustainable groundwater extractions beyond natural recharge rates in some aquifer systems.
- As more than 85 % of the Australian population lives in coastal areas (<50 km) salt-water intrusion into coastal aquifers is a real threat for some locations (Ivkovic et al. 2012).

- Rising groundwater levels and resulting water logging/salinisation of soils due to irrigation is an on-going issue and needs sustained research and groundwater management.
- The use of water of marginal quality for irrigation and recycling causing salinity build-up in the underlying groundwater.
- Groundwater use by mining operations and especially the development of coal seam gas exploitation can introduce new groundwater related problems, which require groundwater research, monitoring and development of new management policies.
- Groundwater Dependent Ecosystems (GDEs) contribute significantly to social, economic, biodiversity and spiritual values (Murray et al. 2003). More knowledge of the specific requirements of GDEs is needed for effective management.
- The application of Managed Aquifer Recharge (MAR) is strongly increasing and has a number of benefits in terms of water management. However, as generally recycled or storm water is used for the recharge any risks of deteriorating water quality and health has to be managed. MAR guidelines have been established (NRMMC 2009).
- Analysis of the climate over the last 80 years shows a warming over most of Australia, increasing rainfall over northern, central and north-western Australia and decreasing rainfall in eastern, south-eastern and south-western Australia. As recharge is more variable than rainfall the effect of climate change on groundwater supplies will be more pronounced in areas of low recharge (Barron et al. 2011). Climate change will increase demand for water for irrigation, cities, wetlands, etc., intensifying the water scarcity.
- The value of water for indigenous Australians for culture, identity, as well as livelihood are poorly understood (CSIRO 2011; Jackson et al. 2012; Liedloff et al. 2013).
- As clearly groundwater management had in Australia a strong focus on quantitative aspects, further development of integrated quantitative-qualitative-ecological and publicly supported policies embedded in socio-economic plans is evident for long-term management of sustainable groundwater resources.

## References

Acworth I, Hazel C, Laws T, Lawrence C (eds) (2009) Australian groundwater school, the notes. National Centre for Groundwater Research and Training, Adelaide

AWRA (2000) Australian water resources assessment 2000. http://www.anra.gov.au/topics/water/pubs/national/water_use.html

Barron OV, Crosbie RS, Charles SP, Dawes WR, Ali R, Evans WR, Cresswell R, Pollock D, Hodgson G, Currie D, Mpelasoka PT, Aryal S, Donn M, Wurcker B (2011) Climate change impact on groundwater resources in Australia, vol 67, Waterlines report series. National Water Commission, Canberra

Burke JJ, Moench MH (2000) Groundwater and society: resources, tensions and opportunities. United Nations, New York. ISBN 92-1-104485-5

CSIRO (2008) Water availability in the Murray-Darling Basin a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields project. CSIRO, Clayton South, 67 pp

CSIRO (2011) In: Prosser IP (ed) Water: science and solutions for Australia. CSIRO Publishing, Collingwood

European Commission (2006) Directive of the European Parliament and the Council on the protection of groundwater against pollution and deterioration. J Eur Comm L372:19

Hamilton DA, Seelbach PW (2011) Michigan's water withdrawal assessment process and internet screening tool. Michigan Department of Natural Resources, Fisheries special report 55, Lansing, 37 p

Hunt RJ, Anderson MP, Kelson VA (1998) Improving a complex finite difference groundwater-flow model through the use of an analytic element screening model. Ground Water 36 (6):1011–1017. doi:10.1111/j.1745-6584.1998.tb02108.x

Ivkovic KM, Marshall SM, Morgan LK, Werner AD, Carey H, Cook S, Sundaram B, Norman R, Wallace L, Caruana L, Dixon-Jain P, Simon D (2012) National-scale vulnerability assessment of seawater intrusion: summary report. Waterlines report no 85. National Water Commission, Canberra

Jackson S, Tan P-L, Mooney C, Hoverman S, White I (2012) Principles and guidelines for good practice in Indigenous engagement in water planning. J Hydrol 474:57–65

Liedloff AC, Woodward EL, Harrington GA, Jackson S (2013) Integrating indigenous ecological and scientific hydro-geological knowledge using a Bayesian network in the context of water resource development. J Hydrol 499:177–187

McKay J (2012) Groundwater management: looking to the future so there is a future. Water Int 37 (7):721–726

Mostert E, Van Beek E, Bouman NWM, Hey E, Savenije HHG, Thissen WAH (1999) River basin management and planning, proceedings of the international workshop on river basin management, The Hague, 27–29 Oct 1999, IHP-V, Technical Documents in Hydrology No 31, UNESCO, pp 24–55

Murray BR, Zeppel MJB, Hose GC, Eamus D (2003) Groundwater-dependent ecosystems in Australia: it's more than just water for rivers. Ecol Manag Restor 4(2):110–113

Murray-Darling Basin Authority (2010) Guide to the proposed basin plan: overview Murray-Darling Basin authority, Canberra. Available from http://www.mdba.gov.au

Murray-Darling Basin Authority (2013) Murray-Darling basin authority, Canberra. Website http://www.mdba.gov.au/. Accessed 8 Sept 2013

NCGRT (2013) Groundwater in Australia. National Centre for Groundwater Research and Training, Adelaide

NLWRA (2001) National land and water resources audit, Australian water resources assessment 2000. Commonwealth of Australia, Canberra

NRMMC (2009) Natural resource management ministerial council, Environmental Protection and Heritage Council (EPHC) & National Health and Medical Research Council (NHMRC) Australian guidelines for water recycling, managing health and environmental risks (phase

2)—managed aquifer recharge, national water quality management strategy. Available at: http://www.ephc.gov.au/taxonomy/term/39

NWC (2013) National Water Commission. Available from http://www.nwc.gov.au/. Accessed 6 Sept 2013

NWQMS (1994) National Water Quality Management Strategy, document 1: water quality management—an outline of the policies. Available from http://www.environment.gov.au/water/publications/quality/index.html

NWQMS (1995) National Water Quality Management Strategy, document 8: guidelines for groundwater protection. Available from http://www.environment.gov.au/water/publications/quality/index.html

Quevauviller P (ed) (2008) Groundwater science and policy—an international overview. RSC Publishing, Cambridge, p 754. ISBN 978-085404-294-4

Reeves HW, Hamilton DA, Seelbach PW, Asher AJ (2009) Groundwater-withdrawal component of the Michigan water-withdrawal screening tool. United States Geological Survey Scientific Investigations report 2009–5003

Steinman AD, Nicholas JR, Seelbach PW, Allan JW, Ruswick F (2011) Science as a fundamental framework for shaping policy discussions regarding the use of groundwater in the State of Michigan: a case study. Water Policy 13:69–86

Tan P-L, Bowmer KH, Mackenzie J (2012) Deliberative tools for meeting the challenges of water planning in Australia. J Hydrol 474:2–10

Wikipedia Contributors (2013) Irrigation in Australia Wikipedia, The Free Encyclopaedia. http://en.wikipedia.org/w/index.php?title=Irrigation_in_Australia&oldid=551808498. Accessed 7 Sept 2013

Winter TC, Rosenberry DO, LaBaugh JW (2003) Where does the ground water in small watersheds come from? Ground Water 41:989–1000. doi:10.1111/j.1745-6584.2003.tb02440.x

Zorn TG, Seelbach PW, Rutherford ES, Wills TC, Cheng S, Wiley MJ (2008) A landscape-scale habitat suitability model to assess effects of flow reduction on fish assemblages in Michigan streams. Michigan Department of Natural Resources, Fisheries research report 2089, Ann Arbor

# Conjunctive Management Through Collective Action

# 9

Cameron Holley, Darren Sinclair, Elena Lopez-Gunn, and Edella Schlager

**Abstract**

This chapter focuses on the interaction between conjunctive management and collective action. Collective action has several characteristics that provide a natural 'fit' with conjunctive management. These include building trust and ownership to enhance water user's acceptance of the need for better and more integrated management and resolving conflict and facilitating trade-offs between and across water users. But what are the opportunities and challenges for conjunctive management through collective action? And what types of settings encourage broad-based collective action by water users and governments? These questions are addressed through a comparative analysis of specific instances of groundwater governance in Australia, Spain, and the western United States of America. For each case, the diverse policy and institutional settings are explained, and consideration given to the motivators for, and successes of, conjunctive management and collective action. The chapter draws comparisons across the cases to suggest lessons on incentives for conjunctive management, as well as exploring its challenges, before identifying future directions for more effective integrated water management.

This research was partially funded by an ARC Discovery Early Career Researcher Award (DE140101216) and an ARC Linkage Grant (LP130100967).

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A.J. Jakeman et al. (eds.), *Integrated Groundwater Management*,
DOI 10.1007/978-3-319-23576-9_9

## 9.1 Introduction

Diverse policy and institutional settings provide different types of incentives for engaging in adaptive integrated cyclical management of surface water and groundwater (aka conjunctive management). This chapter's interest lies in the interaction between conjunctive management and collective action. In particular, it focuses on the opportunities for, and challenges of, conjunctive management and collective action as a combined strategy for managing variable water supply and incorporating options for environmental watering.

While there is no settled, precise definition of conjunctive management, it can be broadly conceived as involving the integration of water management decision-making and action to maximise the benefits arising from the innate characteristics of surface water and groundwater water use (e.g. surface water resources are more visible and measurable, but more variable and typically more difficult to store) (Evans et al. 2012; SKM 2011). Conjunctive management can take various forms, for example, engineered (e.g. aquifer storage and recovery; see Chaps. 16 and 17), non-engineered (e.g. integrated water planning; see Chap. 8 and Ross 2012a), bottom up (e.g. at the farm level of sourcing water from both a well and from an irrigation delivery canal, with some accompanying monitoring and evaluation to develop local management objectives) and top down (e.g. a more strategic approach where surface water and groundwater inputs are centrally managed/planned for) (Evans et al. 2012, pp. 4, 6).

Crucially, conjunctive management is not limited to the coordinated or joint use of surface water and groundwater, but rather the coordinated use of a portfolio of resources, of which groundwater is particularly important for three key reasons. First, groundwater has an in-built advantage during drought since it offers an important buffer to climate variability due to its relative stability (and thus lowers the risk). Second, it is a relatively inexpensive resource when compared to alternative climate independent sources such as desalinated or recycled water, with their comparatively high energy costs. Third, it affords enhanced agency or control to water users such as farmers through devolved decision-making (as compared to surface water systems).

The inherent appeal of conjunctive management lies in the unity (or connectedness) of the hydrological cycle. Recognising that the characteristics of water resources vary according to the relative and particular contributions of surface water and groundwater, this strengthens the case for examining opportunities for collective (and integrated or coordinated) management. Indeed, the use of connected groundwater and surface water systems can have significant implications for both water quantity and quality of each, respectively (Brodie et al. 2007). Abstraction from either can affect the quantity, quality and reliability/accessibility of abstraction from the other, as well as impacting on the water supply to conjunctive dependent ecosystems (e.g. low flows in rivers and certain wetlands) (SKM 2011, p. 4).

Alarmingly, the 'disjointed' use of groundwater can lead to undesirable effects (Lopez-Gunn et al. 2011) ranging from a rise in piezometric levels, increasing the risk of flooding and/or subsidence, problems of drainage and salinisation or marine intrusion, the lowering of piezometric levels and higher pumping costs, and if connected to surface water flows, to a reduction in flows which can negatively affect wetlands, springs, groundwater dependent ecosystems and river base flows. Conversely, conjunctive management in a conscious and coordinated way (Andreu et al. 2010) can ameliorate or even prevent many of these problems. This is where collective action comes into its own by engaging water users as key conjunctive management participants. Overseen by well-designed water rights systems, this can lead to better and more integrated management outcomes. In this respect, collective action can take various forms – between different tiers of government, between government and water users, and between groups of water users themselves (Holley et al. 2011).

Collective action has several characteristics that provide a natural 'fit' with conjunctive management. These include, in particular: the planning and day-to-day management of water; contributing local knowledge to assist in the development of a common understanding of water systems; building trust and ownership to enhance water user's acceptance of the need for better and more integrated management (Baldwin et al. 2012); and resolving conflict and facilitating trade-offs between and across water users (SKM 2011; Brodie et al. 2007, p. 78).

Given these potential attractions, what types of settings encourage broad-based collective action by water users and governments to deliver conjunctive management? And what are the opportunities and challenges for conjunctive management through collective action? These questions are addressed via a comparative analysis of specific instances of groundwater governance in Australia, Spain and the western United States of America, three leaders in water reform and conjunctive management approaches. Each national case study outlines the diverse policy and institutional settings, and considers the motivators for, and successes of, conjunctive management and collective action. Reflecting the diverse forms of conjunctive management, the national cases explore various conjunctive management approaches, including integrated basin and catchment planning in Australia, United States and Spain, as well as augmentation plans/agreements and large-scale water infrastructure projects involving storage and desalination in the United States and Spain. The chapter concludes by drawing comparisons across the cases to suggest lessons on incentives for conjunctive management, as well as exploring its challenges, before identifying future directions for more effective integrated water management.

## 9.2 Conjunctive Management: Experiences from Australia, Spain and the United States of America

### 9.2.1 Australia

By the latter stages of the twentieth century, significant weaknesses in Australia's water regulation began to emerge. In particular, state governments were granting many new water licences to irrigators and others, with generous extraction allocations attached (Bricknell 2010; Gray 2010). Under these arrangements surface water and groundwater resources were generally managed separately (Ross 2012a). Subsequent fears of over-allocation and severe water shortages soon emerged. Broadly speaking, this crisis motivated state and federal governments to come together and collaboratively address accelerating degradation of water sources (Godden and Foerster 2011).

The result was a new national water management regime. Commencing in 1994, and later taking shape under the *National Water Initiative* (NWI) in 2004, Australia came to recognise connectivity between surface water and groundwater resources and the need to manage connected systems as a single resource (Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia, the Australian Capital Territory and the Northern Territory 2004, para 23 (x)). This included acknowledging hydrological connectivity considerations relating to trading of water rights (which have been separated from land), management of environmental water, and most importantly for present purposes, the use of collaborative planning for delivering integrated management of surface water and groundwater (IANWI, paras 58(i), 79(i) (c), Schedule E, 5(ii); NWC 2008, p. 2).

Collaborative planning is now central to the pursuit of conjunctive use management in Australia and is the primary instrument for achieving collective action between governments and water users. As such, NWI principles include consultation with stakeholders, adaptive management of surface water and groundwater systems and consideration of the level of connectivity between surface water and groundwater systems (IANWI, paras 23(x), 25(iv), Schedule E, 5(ii), 6(i)). The concept of connectivity has also been recognised in the recent Murray-Darling Basin Plan (Basin Plan, Cth, 2012, cl10.19).

Individual state jurisdictions have considerable flexibility in how they implement these principles (Tan et al. 2012). In practice, however, water plans commonly contain: rules for water allocation; rules for transferring water entitlements or allocations; environmental outcomes; limits on extraction in certain places or at certain times; and monitoring and reporting requirements (Gray 2012). Conjunctive management is taken into account across these various elements, including in identifying the environmental values and assets, setting the plan's objectives, and choosing the management tools to implement the plan (NWC 2011a, p. 99). Consequently, the number of water plans that recognise surface water and groundwater connectivity is growing (NWC 2011a, p. 99).

Despite this success, conjunctive water management has been piecemeal and slow. For instance, few groundwater dependent ecosystems have well-established environmental water requirements or effective monitoring programs (Lamontagne et al. 2012). Further, while available modelling and data is improving, the historical under-resourcing of data collection and analysis, and limited metering and enforcement of extraction, particularly of groundwater, have inhibited progress (Holley and Sinclair 2013a; Holley and Sinclair 2012; Baldwin et al. 2012, p. 75). Indeed, as the National Water Commission explains, "Quantifying surface and groundwater connectivity and aligning their management is unfinished business in most jurisdictions... While all jurisdictions have developed policies for managing connected surface water and groundwater systems, the implementation of effective conjunctive management remains limited and the understanding of connectivity in individual systems is still inadequate in many areas" (NWC 2011a, pp. 10, 100).

Why has conjunctive management remained ‘unfinished’ in Australia? And what are the opportunities and barriers to conjunctive management and collective action? These issues remain unresolved, not least because answers are likely to vary between states and catchments. A comprehensive review of these experiences is beyond a chapter of this size, so we instead draw some general insights on the challenges and opportunities of conjunctive management through a collaborative planning case study (for further on this study and its methods, see Holley and Sinclair 2013b, pp. 37–38).

New South Wales (NSW) was selected because of its diverse range of surface water and groundwater resources, and it is at the forefront of integrated water management (Ross 2012a). Water sharing plans (WSPs) are employed to address competing demands through rules for water use and trading and are developed under the *Water Management Act 2000* (NSW). The Act gives effect to the NWI goal of sustainable and integrated water management, including the role of the community in working with government to resolve water management issues (*Water Management Act 2000*, s 3). Most NSW WSPs take the form of ‘Minister’s Plans’ rather than as a result of a formal collaborative committee process (Water Management Act 2000, ss15, 50; Holley and Sinclair 2013b; Millar 2005). In making the WSP, the Minister has the power to set up advisory or other committees for the purposes of the *Water Management Act* and, as shown below, this was used in *lieu* of a more formal collaborative committee route (Water Management Act 2000, ss 387, 388).

The first of NSW’s over 60 WSPs commenced in the early 2000s and were prepared using a local committee approach with stakeholder consultation (NWC 2011b, p. 10). This study focuses on the development of one of these earlier plans in a small upper catchment in the Namoi Valley, chosen because its surface water channels exhibit a number of points of high connectivity with the local groundwater system (SWS 2012, pp. vii, 103; Parsons et al. 2008; Kelly et al. 2007). The particular ‘zone’ is subject to the *Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources 2003* (covering 13 zones in total).

The catchment has a single river flowing through it, but this is usually dry as it sits on top of a porous alluvial groundwater system, which is rapidly recharged from the surface river water. In short, it is a highly connected system. The catchment is populated by a comparatively small number of farmers (with 33 licence holders, but only around 15 active water users), with small holdings (around 40 ha). Other major stakeholders engaged in water management were a government department for water (the New South Wales Office of Water (NOW) (now known as DPI Water)), the Namoi Catchment Management Authority (CMA) (now known as North West Local Land Services), a number of local councils and other property holders who did not actively use the groundwater.

Notwithstanding that much of the groundwater resource is highly connected to the Namoi River, the development of our groundwater WSP case was separated from a surface WSP in the Namoi (NWC 2011b, p. 130). Both WSP’s began as single resource drafts prior to the NWI being agreed at the national level. While the NWI was finalised before the groundwater WSP was completed, the ultimate plan provide little information on the potential connectivity between surface water and groundwater (NWC 2011b, p. 131).

The groundwater planning process began with the release of a socioeconomic study into the region, followed by some initial consultation meetings in each zone of the Namoi Valley (approximately 42,000 km$^2$ in total, containing 100,000 people) along with a series of related technical studies. With the *Water Management Act* in place in 2000, a groundwater management committee was established to cover the Namoi region. The committee included representatives from all the major stakeholder groups highlighted above, and other relevant department and fishing bodies, and had responsibility for developing the draft WSP, which it released in 2002 (Millar 2005, p. 9). Up to this point, there was little direct consultation with stakeholders outside of the committee process (Holley and Sinclair 2013b).

The draft WSP was scheduled to begin operation in 2003 and was to be made under s50 of the *Water Management Act* as a Minister's Plan. Following some controversy over the operation and amendment of s50 to exclude certain requirements relating to public consultation, and an unsuccessful legal challenge the WSP was put on hold while a review of the draft plan was undertaken (Millar 2005). This engaged representatives from peak irrigation bodies, and addressed in particular the issue of uniform and proportional reductions versus allocation based (at least partially) on 'history of use'. In order to execute this policy the implementation of six groundwater plans was deferred so the department could establish accurate information on the historical rates of extraction for all licensees (Gardner et al. 2009, p. 320). Subsequently, a new revised WSP was completed in 2005, and was scheduled to commence in 2006. In the interim, another far more comprehensive round of consultation was undertaken with the assistance of the existing stakeholder committee and the Namoi CMA. In terms of impact, the CMA consultation process amended approximately a third of the clauses in the draft WSP. The Minister approved the WSP, with the weighting of allocations favouring active users over inactive users (see also New South Wales Government NSWG 2011). The WSP came into force on 1 November 2006, and terminates on 30 June 2017.

While there were some disagreements over the mechanics of the above consultation process, there were also key differences and disputes over its nature and outcomes. These differing perceptions are fundamental to understanding the failure of conjunctive management in this instance, and reveal ongoing unresolved disputes between the different actors. Although there was, and remains, some tension regarding entitlement reductions, of fundamental relevance were disputes between government and non-government stakeholders. Holley and Sinclair's (2013b, pp. 44–50) research on the experiences of this case study zone reveal four key areas of contention.

First the zone's irrigators and NOW disagree as to the nature and content of the consultation process that led to final WSP. In particular, the irrigators reported that they were deceived by NOW as to a proposal for integrated water management involving variable groundwater allocations that reflected highly connected surface water and groundwater system and resulting rapid aquifer recharge by a stream in their zone. The underlying rationale of the irrigators' case was that the rapid aquifer recharge in their zone could have been better harnessed to optimise water use during wet and dry periods, including exploring storage options and more flexible annual allocations. In essence, this would have entailed management rules that were more responsive to changing aquifer levels via a seasonal allocation of the catchment as a whole, as opposed to a fixed sustainable yield as is common under WSPs. For the irrigators, a more integrated planning process would have allowed them to make trade-offs between flexibility and the security of water entitlements in order to make better use of existing water supplies. This would have required frequent monitoring of the catchment aquifer and river flows, such that water use protected environmental flows. The rationale for this approach was that farmers would be able to engage in a cooperative form of local governance (with external oversight), in particular, adapting their management strategies in response to changes in river flows and aquifer levels.

The irrigators believe they were given a firm undertaking by NOW (and its predecessors) to seriously consider their proposal to respond to their catchments biophysical conditions and put in place flexible integrated seasonally variable targets: "they said they would look at it". In contrast, the government claims no such undertaking was given, nor did they receive any written proposals to that effect from the irrigators. These different interpretations emerged from a decision-making and consultation process that saw significant mistrust and disconnection between government and the irrigators. One irrigator was of the view that "the [proposal] fell over because farmers were not respected by NOW, and were not trusted to manage the groundwater". Whilst not agreeing with the irrigators' interpretation of events, even NOW respondents acknowledged that shortcomings in the consultation process for the irrigators (discussed further below) had contributed to these fundamental divisions.

Despite the support of local farmers, in the end, the suggested management approach was not adopted. The opportunities for more flexible exchanges between different uses was instead overlooked in favour of groundwater only WSP, where water users were given annual allocations that were tied to groundwater levels in the catchment.

A second area of contention was the negotiation process in the lead up to the WSP zone allocations. On all accounts, the process was time consuming but had successfully involved many peak groups and, in the later stages, many farmers. Even so, smaller irrigators and local farmers believe they ultimately had little say (let alone an opportunity to contribute to a consensus agreement) in a decision-making process that was dominated by large, downstream cotton irrigators and governments. NOW respondents also acknowledged shortcomings in the consultation process for the case study's irrigators, particularly in earlier stages:

> There wasn't a lot of consultation at local level with irrigators . . . I don't know how up to date they were on what was happening and the decisions being made above them. They were out of the loop really. Government and peak irrigators were the main groups really throughout the entire process

Third, even when the CMA engaged local irrigators in the latter stages of the process, there were reportedly significant weaknesses in facilitating meaningful negotiation. Although NOW and the CMA had provided significant technical information on water conditions and hydrological modelling, and that some connectivity estimates were incorporated into their underlying hydrological models

(NWC 2011b), sufficient information was not always available to properly account for groundwater-surface water interactions (Lamontagne et al. 2012). At the time, stakeholders raised questions about the information used to assist with complex decision-making. As one government respondent put it: “I guess by its nature, complicated was necessary”. According to respondents, the lack of sufficient government assistance effectively precluded many local irrigators from fully understanding and inputting into issues of connectivity and the implications for conjunctive management. As one government respondent explained:

> Another issue was the complexity of the model – because of this complexity, some irrigators never really got it . . . You know you will always have people at one end of the room who are switched on, and then you will have others who enjoy farming but not following up issues and reading things. In hindsight some of the presentations could have been simpler.

Fourth, and finally, and perhaps the biggest weakness, was that despite models underpinning the WSPs, the resulting plan lacked sufficient provisions for integrated management of connectivity (NWC 2011b, p. 14). Arguably, this has constrained adaptation opportunities and the incorporation of conjunctive management approaches. Indeed, even if one has faith in the fact that hydrological models underpinning the plan continue to reflect aspects of connectivity modelling itself, sufficient information is reportedly not always available to account for groundwater–surface water exchanges in detail. Indeed, respondents pointed out that relevant government agencies have failed to generate and share relevant hydrological data, including an absence of information on their groundwater aquifer status and trends (Holley and Sinclair 2011). As one catchment management respondent noted, “they [NOW] are supposed to do Aquifer Status reports on a quarterly basis, but we are lucky if we get a report every three years”.

There was a similar lack of sustained data sharing/dialogue between state and regional institutions and the water users themselves, namely, the farmers. Following the implementation of the WSP, it was claimed by catchment management respondents that at first “the Department came along with good reports, but then this stopped and people quickly lost interest”. Consequently, the farmer consultation groups became dormant. Despite the availability of some data online, farmers said they lacked the time and skills to find, access, use and then interpret relevant information: “they tell us it’s in the public domain but they can’t find the time to show us how to get to it and look at it” (Holley and Sinclair 2011). In the absence of such data, effective water management (including ongoing monitoring and scrutiny of the WSP itself) is difficult, with minimal information reported on the achievement of environmental or cultural outcomes, or progress towards these (NWC 2011b, p. 131).

Despite recent recognition of these issues there is still a long way to go until successful conjunctive management of groundwater can be realised in catchments such as this case study. Certainty, there are limits to generalising from a single case (e.g. see the distinct history of developments relating to conjunctive management of seawater intrusion, Petheram et al. 2008). However many of these findings appear consistent with recent national evaluations (NWC 2011a). It is also important to remember that the case study was an early example of planning. The new Basin Plan (Basin Plan 2012, Cth, cl10.19), ongoing review of WSPs in NSW (NSW Office of Water 2013; NRC 2013) and new integrated and macro plans that aggregate water sources into broader management units (O'Rourke and Bailey 2010) provide evidence and opportunities for necessary refinement to management of groundwater surface water connections (NWC 2011b, p. 11). For example, the recent *Water Sharing Plan for the Peel Valley Regulated*, *Unregulated*, *Alluvium and Fractured Rock Water Sources 2010* represents a substantial advancement in NSW's approach to integrated management of surface water and groundwater, including different sets of rules to manage water resources with varying degrees of connectivity (e.g. shallow alluvial groundwater below a river channel can be managed by the same rules as surface water, whereas groundwater remote from the river channel is managed as a separate resource) (Ross 2012b). Positive signs for conjunctive management are also evident in the growth of managed aquifer recharge (whose uptake in Australia has been patchy among different states, Dillon et al. 2009, 2010) and national efforts to improving resource condition data (Water Regulations 2008, Cth, Part 7). However, the full potential and impact of these developments is still some years away, and it is clear that despite over a decade of national objectives the implementation of conjunctive water systems through planning is lagging.

### 9.2.2 Spain

Conjunctive water use is widespread in Spain, both in the interior (e.g. Madrid's water supply as the capital region is now underpinned by conjunctive use) (Flores Montoya 1998), and along the Mediterranean coast, all the way from the internal basins of Catalonia, down to the Jucar, the Segura and finally the Almeria basin. Two features are peculiar to conjunctive use. The first is the role of water user groups in the management of this conjunctive use. The second is the fact that conjunctive use along the Mediterranean coastline (where there are high value crops and economically important tourism) is seeking to enlarge the portfolio of resources to reduce risk beyond surface water and groundwater, and is now incorporating desalinated, recycled and even recharged water (López-Gunn et al. 2012). This means that management is complex both from the perspective of resource management, and also in terms of coordination between a number of actors. The leading ones are, however, the water user groups as ground managers, and the respective river basin authority as the regulator.

Groundwater in Spain is a strategic resource in a number of basins and states (Sahuquillo 2009). It is not a particularly noticeable resource in the Northern part, whereas in parts of central Spain, like La Mancha or Almeria, it is the key water resource for the regional economy. In the case of Catalonia, conjunctive water use is part of day-to-day management, with a highly complex system of resource management. People and economic activity has concentrated along the coastline, where intensive groundwater use has led to problems with both marine intrusion and water quality, for example in the deltas of the Llobregat, Besos, Ter, Muga and Francoli rivers (Planas 2010). Intensive use affects the cities in the region, and has led to a complex management including built seawater barriers to prevent marine intrusion and projects for aquifer recharge. The experiences on aquifer recharge in the Besós and Llobregat rivers (Barcelona) are complemented with the pilot experience with the Río Belcaire (Castellón), which together represent 50 $Mcm^3$/year for the whole of Spain (Andreu et al. 2010).

However in terms of resource use, what is noticeable is that rather than conjunctive use it is a case of 'alternate' use, i.e. surplus surface water is used to recharge local aquifers for times when there is low surface water availability. The case of the Cubeta de San Andreu is interesting because of the confluence between complex resource use and a complex institutional framework that is needed for the conjunctive use to run smoothly. The current plan for water resources is based on the joint use of surface, groundwater, re-used water and desalination and water transfers. This is a change from individual use to collective management, led under the umbrella groundwater user group for Catalonia, the specific one of the Cubeta de San Andreu, the public water supply company ATLL, and the regional water administration through specific agreements.

The agreement signed between users and the regional water agency provides a framework for a project of joint interest, e.g. aquifer recharge, covering technical, legal and economic aspects. It includes aspects related to aquifer recharge, inventory of water rights and the closing of some wells, the installation of water meters and monitoring, technical advice, a chemical monitoring network and preparatory work for the EU Water Framework Directive (WFD). Thus the goals or objectives are both public and private. The main obstacles have been to reach enough level of association and common vision, and closer links between administration agencies (like agriculture and water admin), as well as giving political voice and representation to users in the decision-making bodies.

The case of Andalusia, in particular, the region of Almeria, bears some similarities to the case of Arizona, except with one major difference: it is for use in the largest greenhouse area in the world, the so-called 'plasticulture'.

In the late 1990s to early 2000, with a lack of groundwater management in the southern Mediterranean coastal belt, authorities looked to divert water from the Ebro river in the north to help compensate for rapidly depleting aquifers (Llamas et al. 2007). Water agencies tend to build projects far in advance of their justifiable need on pure economic terms (Howe 2002). It is politically rational for decision makers to prefer users to continue pumping than to take the (unpopular) decision to cut allocations and instead opt for politically more popular water transfers. There are very few systems of explicit conjunctive management. Once the National Hydrological Plan of 2001 was derailed, Plan B centred on the construction of a series of desalination plants along the coast, including Almeria. However, Spanish farmers – like Arizona farmers – also balked at paying for expensive desalinated water in bulk to substitute groundwater abstractions. However, in an ironic twist, farmers do use desalinated water – which they consider 'fresh' to blend it with highly salinised groundwater with high conductivities, which is an optimal solution in terms of lowering the risk of no water, while ensuring optimal conductivity for high value tomato crops destined for export in Northern Europe. Farmers prefer cheaper groundwater to desalinated water, despite the fact that desalinated water prices are subsidised and do not reflect the true costs (which are borne by the taxpayer).

The case of Jaen in the Upper Guadalquivir basin offers a completely different narrative. Here, the discussion on conjunctive use is happening at the basin level, partly because groundwater farmers upstream started intensive use of relatively small aquifers, using water that technically was already 'allocated' to farmers downstream. However farmers downstream were more 'inefficient' in terms of Euros per drop (productivity) and also in terms of resource use ($m^3$ per crop) which has created a negotiation space. Intensive groundwater use upstream has meant the rapid development of a region that was economically depressed, and where there are now political pressures to keep these captured resources. Since in Spain, contrary to the United States, there is no prior appropriation doctrine, it is the river basin authority through basin planning that becomes the object of negotiation for groundwater user communities upstream and surface water communities downstream. In one case, defending what are rather tenuous 'use' rights as compared to full 'de jure' water rights. Yet it is an example where once this intensive groundwater use has happened (it is *fait accompli*), the most likely scenario is to upscale collective action to basin level in order to achieve the best possible 'conjunctive' use of both surface water and groundwater resources (Rica et al. 2014).

Looking at the Jucar case we see an interesting evolution in terms of conjunctive use, from really early experiences dating to the early twentieth century, all the way to current decisions being posed on conjunctive use on the river basin plan being prepared in 2013. In this context the case of the river Mijares and irrigation in the Plain of Castellon is a good example of conjunctive management, defined as consisting both of the joint (or alternate) use (resource organization) and joint use by users (social organization). An agreement was signed in 1970 to use water from the Mijares River (*Convenio de bases para la ordenación de las aguas del río Mijares*, *1970*, *OM-MOP-73*), based on making use of the storage capacity of the aquifer (estimated at 600 $Mcm^3$) five times larger than the reservoirs of Sichar and Maria Cristina, which had filtrations. Thus during dry periods use is made of groundwater which is recharged during the wetter years by making use of surplus flows from surface irrigation in the *acequias* or canals (Andreu et al. 2010).

The Jucar case offers some similarities to the case of Colorado, in the United States, and to the case of the Guadalquivir, with a classic conflict between intensive use of groundwater upstream and impacts on surface water users downstream. In the first instance, like in other cases discussed in this chapter, there was a negotiation between farmers in the Eastern Mancha aquifer in Albacete with the Jucar river basin authority. However, during times of high water scarcity – in the midst of a drought – like in the case of Colorado, the temporary solution was an augmentation plan, to address the problem of low flows in the Jucar river, which eventually impacted downstream into the *Acequia Real del Jucar* (a traditional surface water irrigation area highly dependent on these flows). The Water Act of 1999 introduced

**Table 9.1** Results Ofertas Públicas de Adquisición de Derechos (OPAD)

| | 2007 | 2008 |
|---|---|---|
| Applications submitted: | 119 | 234 |
| Volume in rights (Mcm$^3$) | 56.8 | 109.6 |
| Volume waived without economic compensation (Mcm$^3$) | 22.9 | 12.5 |
| Volume offered (Mcm$^3$) | 27.3 | 50.6 |
| Budget used (million €) | 5.5 | 12.7 |
| Reserved volume (Mcm$^3$) | 6.6 | 46.5 |

Source: Ferrer and Garijo 2013

an important change by partially introducing market instruments under the figures of contract for the assignment of rights (Article 67 TRLA) and a centre for the exchange of water rights (Article 71 TRLA) (Ferrer and Garijo 2013). The first case has not been used frequently between users because it is fairly restrictive on the type of water right. Most groundwater rights are private and these are barred from participating in water rights exchanges. In the 2005–2008 drought, however, the river basin authority negotiated with Eastern Mancha farmers for an area of 28,000 ha on the basis of a series of criteria centred on impact on river flows and price offered. Exchange purchases went from 20 % to 5 % of the irrigation, securing 148 Mcm$^3$ bought with (temporary) reductions to prevent the drying up of the river bed as had occurred in the previous drought from 1994 to 1996.

It is important to stress that it is likely that this negotiation and agreement was facilitated to a large degree due to the existence of a well-organised and cohesive groundwater user group that acted as interlocutor with the river basin authority. Thus after the emergency meeting due to drought from the Spanish Council of Ministers in 2004, Centres for the Exchange of rights (art. 71) were set up in the Guadiana, Júcar y Segura which authorised these basins to undertake Public Offers for the (temporary) Acquisition of Rights (*Ofertas Públicas de Adquisición de Derechos* (OPAD)) (Table 9.1).

During the 2006–2008 drought other types of conjunctive management were undertaken in the Jucar, including the use of non-conventional resources like drainage flows from the Ribera del Jucar of up to 60 Mcm$^3$/year via pumping (costs paid by users); and water re-use (up to 94 Mcm$^3$/year) where treated water from Valencia city was partially exchanged for surface water in the Vega del Turia thus freeing up Jucar resources. These were initiatives for conjunctive use using all available resources and using a modelling programme to explore the different options, including leading to a better comprehension by users of the range of alternatives (Andreu et al. 2010).

The Jucar case is one of the best studied and most complex in Spain and one which highlights a range of available models for conjunctive use as discussed by Garduño et al. (2010). Equally, Andreu (a Spanish expert on conjunctive use (Andreu et al. 1996; Andreu et al. 2010)), highlights the diversity of experiences in Spain on conjunctive use not discussed here for reasons of space, and the common denominator for their durability: success centred on collective action and adequate rules of game, which have to envisage different scenarios, give particular emphasis to drought conditions and define the economic regime. What is particularly relevant at a more macro scale from the perspective of joint use and collective action is to make more flexible the opportunities for exchanges between different uses as argued by Ferrer and Garijo (2013). At the catchment level scale, conjunctive use of water opens up an interesting constellation of mutual interests between surface water and groundwater, public water supply and irrigation and the most suitable use of best quality water. Transfer of rents between sectors from those that have a higher capacity to pay could also solve one of the most intractable problems in the basin.

In conclusion, conjunctive management in Spain is a reality in many cases and it has become particularly valuable as a solution to complex problems, where in general the complexity of the resource use has been matched by the emergence of parallel social institutions and collective entities to address conjunctive management.

### 9.2.3 United States of America

In the United States, the primary authority over the allocation of ground and surface water resides with states. Each state has its own water laws and water administration system making it difficult to generalise about water policy in the United States (Getches 2008). Although the states are the lead actors in deciding whether and how conjunctive management occurs, the federal government is often a participant because of its authority over different activities that impact water. Beginning in the early twentieth century, the federal government began a long-term program of financing and building large surface water storage and delivery projects (Reisner 1993). The projects are often sources of water for conjunctive management programs. Later, in the 1970s, environmental laws extended the reach of the federal government. In particular, the Endangered Species Act has impacted how states and their water users place water to productive uses (Aiken 1999).

Since it is impossible to adequately address the water experiences of each of the 50 states, this section focuses on the experiences of three western states, Arizona, Colorado, and Nebraska. These three states were selected because of their variation in water administration that in turn has affected their experiences with conjunctive water management. Arizona's water arrangements are highly centralised within the Arizona Department of Water Resources (ADWR), which administers groundwater and conjunctive water management programs. Local jurisdictions, such as irrigation districts, cities and counties deliver water to end users, but have limited discretion in governing water (Colby and Jacobs 2007). In contrast, Nebraska's water arrangements are highly fragmented. Local natural resources districts have the primary authority to manage groundwater, whereas the Nebraska Department of Natural Resources has the authority to manage surface water (Harnsbarger 1984). Until very recently, the state held minimal decision making authority over groundwater, thus making it difficult to coordinate groundwater and surface water uses.

Finally, Colorado may be characterised as more of a polycentric system. Concurrent and overlapping powers to govern water are shared across the three branches of government – specialised water courts, the state water engineer, and the legislature – with water users organised in irrigation districts and companies, well associations, and municipal water utilities (Blomquist et al. 2004). No single branch of government or local or regional water organization dominates water governance.

While each state's water laws, administration, and experiences are different, each state turned to conjunctive water management to provide solutions to a series of conflicts confronting water users and the state governments. It is the nature of the conflicts, combined with the state's water laws and water geography that shaped conjunctive water management responses. For Arizona, conjunctive water management emerged from conflicts over how to develop and use its allocation of Colorado River water. Allotted over 2 million acre feet of water annually from the river, it required a multi-billion dollar project of canals and pumping stations to deliver a substantial portion of that water to the most populous areas of the state. One of a number of conditions that Arizona accepted in order for the US Bureau of Reclamation to build the $(US) 4.8 billion Central Arizona Project was to adopt a new state groundwater code that would regulate groundwater pumping and limit the mining of groundwater (Leshy and Belanger 1988). The 1980 *Arizona Groundwater Management Act* established the framework for conjunctive management. It created four active management areas (AMAs), later expanded to five when one of the original AMAs was split in two, extending from central Arizona south to the international border with Mexico. Within the active management areas, agricultural groundwater rights were quantified and capped and municipalities were subject to limits and over time reductions in the amounts of groundwater they could pump to serve their residents (Leshy and Belanger 1988). The portions of Arizona not covered by active management areas continued under the historic groundwater regulatory regime of reasonable use (Colby and Jacobs 2007).

By the early 1990s, the Central Arizona Project was complete and began delivering water, however, the state faced a serious crisis. The state intended to repay its portion of the cost of constructing the project by selling water. The primary water users, irrigators, balked at purchasing the water because it was substantially more expensive than pumping groundwater. Over the course of several years, negotiations among the Federal government, state, and municipal, agricultural, and rural interests resulted in revisions to the 1980 *Groundwater Management Act*, some of which encouraged the recharge of Central Arizona Project water underground to be withdrawn at a later date (Glennon 1995). Large water districts, municipal utilities, and the Arizona Water Banking Authority have developed a series of direct and indirect recharge projects storing several million acre feet of water over the past decade. For instance, from 1997 to 2012, the Arizona Water Banking Authority which recharges 'surplus' Central Arizona Project water has accumulated over 3 million acre feet of recharge credits (Arizona Water Banking Authority 2013).

Arizona has a highly focused and directed conjunctive water management program – long term underground storage of its allotment of Colorado River water. The millions of recharge credits are likely to become an important source of water for irrigators and municipal water providers in the next couple of decades because of anticipated water shortages in the Colorado River Basin due to extended drought and climate change impacts.

Colorado, like Arizona, also has active conjunctive management programs and projects in place in the most heavily populated river basins in the state. However, the conflicts that stimulated a conjunctive management response and the resulting practice of conjunctive management are distinct. The first century of European settlement and economic development, roughly between 1849 and 1949, was supported by the construction of surface water storage and distribution systems. Water development was based on and supported by the prior appropriation doctrine in which water is allocated on a first in time, first in right basis. During times of scarcity, those water users most senior in time receive their water allotments while those more junior in time bear the water shortages. The State Water Engineer administers water rights and develops information for water courts to guide the creation, modification, and transfer of water rights. Water courts are the venue in which water users bargain, negotiate, and contest over water rights (Blomquist et al. 2004).

Beginning in the 1950s, irrigators began installing high capacity wells. Within a decade, groundwater pumping began to noticeably affect river and stream flows. Under Colorado water law, groundwater that is hydrologically connected to surface waters is governed under the prior appropriation doctrine. In practice, this meant that groundwater rights were junior to surface water rights and under the prior appropriation doctrine wells should not be pumped until surface water rights were satisfied. Such a strict application of the prior appropriation doctrine would shut off access to a major source of water, one that is particularly important during times of drought, and limit the expansion of irrigated agriculture and municipal and industrial development. Conflict between Colorado surface water and groundwater users also spilled across state borders as water users in downstream states claimed that they were being denied their rights to water by groundwater pumping occurring upstream in Colorado. Efforts to incorporate groundwater into the state's prior appropriation system and to ensure that interstate water allocation agreements are adhered to largely rest on conjunctive management programs and projects (Blomquist et al. 2004).

In Colorado, conjunctive management protects and maintains surface water flows while allowing for groundwater pumping. The state legislature passed a series of laws that gave the state water engineer the authority to engage in rule making and that allowed for the development and use of augmentation plans. Augmentation plans, which must be approved by water courts (as must any rules and regulations developed by the State Water Engineer), allow well owners to augment stream flows to cover the effects of groundwater pumping. Augmentation plans may take a variety of forms. Well owners may lease surface project water and make it available to the Colorado state water engineer to release to the stream or river when needed. Or, they may purchase surface water rights and leave the associated water in the stream to cover the effects of groundwater pumping. Or, some irrigation companies and districts run surface water in irrigation ditches and ponds, allowing it to percolate into the ground and eventually return to the river to cover the effects of groundwater pumping (Blomquist et al. 2004). Wells not covered by court approved augmentation plans have been shut down (Cowan 2012).

Like Colorado, Nebraska's conjunctive water management efforts have been directed at protecting and maintaining river and stream flows. Surface water is governed by the prior appropriation doctrine and is administered by the Department of Natural Resources. Groundwater is governed by local natural resources districts that have the authority to regulate groundwater access and use. Each district is governed by an elected board, and elected members are typically irrigators who pump groundwater. Until recently, the state had no authority over groundwater and natural resource districts were not required to pay attention to the effects of groundwater pumping on surface water flows (Schlager and Blomquist 2008).

The efforts to coordinate groundwater and surface water use occurred because of crises in relation to surface water users. In the Platte River Basin the surface water users were endangered species and in the Republican River Basin the surface water users resided in the downstream state who claimed that Nebraska groundwater pumpers were in violation of an interstate water sharing agreement. The endangered species in the Platte River Basin limited new water development and threatened existing water uses that required permits from federal agencies (Aiken 1999). Most importantly for Nebraska, the state's largest water and electric utility held permits issued by the Federal Electric Regulatory Commission to operate hydroelectric dams that were soon to expire. Permit renewal would require aggressive actions to protect endangered species. The two upstream states in the basin faced similar threats to their water projects as well. The three states and the federal government, over the course of a decade, negotiated an agreement that provided additional flows to the river for endangered species recovery and to cover all water development that affected the river from 1997 onward (Schlager and Blomquist 2008; Freeman 2010; Kenny 2011). One of the sticking points in achieving an agreement was Nebraska actively regulating groundwater wells and pumping in the basin. The upstream states did not want to provide additional water to the river only to have it diverted by irrigators in Nebraska (Freeman 2010). At about the same time, the 1990s, the state and irrigators in the Republican River Basin were gearing up for a US Supreme Court suit brought by Kansas, the downstream state claiming that Nebraska's well owners were diverting water that belonged to Kansas irrigators, causing Nebraska to violate its water sharing agreement. The Supreme Court found in favour of Kansas and required Nebraska to regulate groundwater pumping (Schlager et al. 2012).

Nebraska and its water users struggled to develop an agreed upon process for spanning the chasm between the surface water and groundwater management systems. Over the course of a decade (1994–2004), which witnessed a variety of experiments to settle the intense conflict between surface and groundwater users, the legislature finally adopted a statute that established an integrated water management planning process (Nebraska Department of Natural Resources 2006). The Nebraska Department of Natural Resources (NDNR) was granted the authority to declare river basins fully allocated or over allocated. Once such a designation occurred, the NDNR and the affected natural resources districts were required to collaborate to develop integrated management plans. The Platte and the Republican Rivers natural resources districts were the first to develop such plans (Nebraska Department of Natural Resources 2006).

Integrated Management Plans form the foundation for conjunctive water management in Nebraska. Well moratoria and strict pumping limits reduce the pressure on surface water flows. In addition, several districts in the Platte River Basin are experimenting with groundwater recharge projects by placing water in unlined canals and pits to percolate underground (Bradley 2011). While conflicts continue to simmer among the state's groundwater and surface water users and between water users and state agencies, the era of integrated or conjunctive management has arrived in Nebraska.

The form and function of conjunctive water management varies across the states as do the processes and outcomes of such management. The states differ on how broadly based collective action occurs, or to put it another way, the interests and values that are represented in decision-making processes. In Colorado, broad-based participation is built into the water administration system. Individuals, organizations, and state agencies who hold water rights or who regulate water rights have a seat at the table and that table is typically the water court. Any water rights holder who believes his or her water right will be affected by a decision may participate in court processes. Given such a process, the State Water Engineer, as a routine matter, convenes advisory groups consisting of water rights holders to guide the development of regulations before they are brought before a water court for approval. In Nebraska, participation occurs in a more ad hoc fashion. When substantive legislation is required to address water issues, the legislature often convenes commissions and task forces with representatives of different types of water uses from across the state to hold hearings, conduct investigations, and make proposals. In developing integrated management plans, temporary advisory committees may be established to participate in their development. The Arizona water administrative system allows for much more limited participation in conjunctive management processes. Participation involves organizations and agencies with access to Central Arizona Project water and with the financial wherewithal to engage in larger scale conjunctive management projects. A number of interests and uses have been excluded from pursuing different forms of conjunctive management, most notably those that are organised around perennial rivers outside of active management areas. Since state law does not recognise the hydrologic connection between ground and surface water, nor does it provide local jurisdictions with any policy tools to regulate groundwater, rivers are slowly being desiccated with little that surface water rights holders, recreationists, and environmentalists can do (Glennon 2002).

Conjunctive management represents a key form of adaptation to changing biophysical and societal demands among the three states. For Arizona, conjunctive management represented a response to a societal crisis, but later morphed into a response to changing biophysical demands. When the primary beneficiaries –

groundwater irrigators – of a major surface water project were financially incapable of utilizing the project leaving the state in debt and with surplus water, conjunctive management was adopted. Now conjunctive management is viewed as a key tool in buffering water users against the effects of climate change.

For Colorado and Nebraska, conjunctive management was an important response to biophysical issues that generated conflict. The hydrologic connection between surface water and groundwater had to be actively managed in order to protect surface water flows and the users dependent on those flows. In addition, conjunctive management allows Colorado and Nebraska water users to make trade-offs between flexibility and security of water rights in order to make better use of existing water supplies. For Colorado, augmentation plans provided flexibility – allowing for groundwater use to occur, while also protecting surface water rights. Integrated management plans play a similar role in Nebraska – securing surface water rights and flows while allowing for continued use of groundwater. In turn, integrated management plans set the stage for the development of different forms of conjunctive management.

All three states – Arizona, Colorado, and Nebraska – have witnessed success with conjunctive management. Conjunctive management has allowed water users and the states to address various water related crises and makes possible more active forms of water management. However, each state's conjunctive water management programs also exhibit some limitations. First, environmental issues receive little attention. True, Nebraska is using conjunctive management to recover endangered species on the Platte River, however, that is the price the state must pay in order to protect existing water uses and allow for new water uses in the future. Coordinating the use of hydrologically connected ground and surface water would also allow Arizona to protect relatively rare riparian habitat and the rights of surface water users, but, thus far, the legislature has not been convinced to act. Second, the states have just begun to tap the potential of conjunctive management. The states could more actively coordinate groundwater and surface water use by allowing surface water users to move to groundwater during droughts, with water remaining in streams and rivers to provide for habitat and species protection and for downstream water uses, while limiting pumping and actively storing water underground during wet years. However, such flexibility would come at the potential cost of security of water rights as pumps may not be shut off during wet years.

## 9.3 Discussion and Conclusion

This chapter has shed light on specific instances of conjunctive management and collective action in Australia, Spain and the United States. The nature of these approaches varied, including examples of integrated basin and catchment planning in Australia, Nebraska and Upper Guadalquivir basin; large scale water infrastructure projects involving storage and desalination in Arizona and Almeria; as well as augmentation plans and other agreements in Colorado, Jucar and Catalonia.

Each had considerable success. Australia's 'top down' water reforms involving national frameworks and state implementation gave rise to a suite of legislation and policy instruments and plans that recognise the importance of managing connected water systems as a single resource. In the United States, the more limited national role produced significant variation among states in their conjunctive management approach, but all three demonstrated success, not least facilitating water users and the states to address various water related crises through more active forms of water management. Finally, in Spain's hybrid and multilevel system, involving regulation, voluntary agreements and informal water markets/trading, conjunctive management is tackling various complex problems across a range of water resources. This approach encompasses the ability to engage with water users groups to create a shared vision and accommodate groundwater recharging through formal agreements. It also has facilitated links between administrative agencies to establish consistent conjunctive management approaches.

However, in their own ways, the experiences in each country also evidenced a number of limitations and challenges. In Australia, despite clear national objectives, the implementation of conjunctive water management via collaborative planning has been patchy. Groundwater and surface water remain siloed, science on connectivity was limited and key water user stakeholders were marginalised from integrated decision-making (Lamontagne et al. 2012, p. i). In terms of collective action, consultation was often inadequate, with a lack of meaningful dialogue, poor information and an absence of time and skill on the part of water users. Smaller users, in particular, felt disenfranchised from the process. In the United States, conjunctive management policy also lagged in some areas, including limited attention being given by the legislature and others to environmental issues, and an absence of more active coordination of groundwater and surface water use. In Arizona, in particular, collective action through the participation of water users in the management process was absent, and in Colorado, such participation was largely limited to the legal and regulatory development phase, as opposed to ongoing management. Although more advanced in pursuing collective action than Australian and the United States, Spain, too, has confronted conjunctive management challenges. There are lingering tensions between groundwater and surface water users, and between upstream and downstream users, both of which may be exacerbated in drought conditions. Further, the political voice of water user groups, and their subsequent participation in decision-making, has been less than ideal.

What broader comparative lessons can be gleaned from these case studies? While there are inherent dangers in generalizing from this type of research, nevertheless, a number of insights can be drawn from our findings across the different contexts and institutional arrangements of the three countries. They suggest some key lessons with regard to the types of settings that facilitate conjunctive management and collective action, and also associated challenges and limitations.

In terms of encouraging a participatory approach to conjunctive management, the case study findings support the proposition that governments and water users are more likely to pursue conjunctive management *where social and environmental* *crisis arise*. Such crises included over-allocation in Australia, fights spurned by endangered species (Platte River Basin in Nebraska), conflicts between water users in the United States (e.g. Colorado) and Spain (e.g. Jucar and Guadalquivir), battles over how to develop and use allocations (e.g. Arizona and Almeria) and a mix of pressing water problems including marine intrusion, water quality and low surface water availability (Catalonia). Certainly, the ultimate shape of the conjunctive water management responses may vary according to the nature of the crisis (as well as other institutional variables), however, collectively, the findings suggest that its presence is a powerful motivator for parties to engage in conjunctive management.

The case studies reveal a second condition that encourages and enables conjunctive management through collective action, that is, *institutional recognition of hydrological connections* (between ground and surface water), including, in particular, *the devolution of management tools to water users on the ground*. The importance of this condition was notable by the impact of its absence in the NSW case study from Australia, as well as limiting access to conjunctive management in Arizona in the United States. In NSW, the policy framework promoted a vision of connectivity and integrated management of surface water and groundwater, however this vision was not translated effectively into state government action and rules. Groundwater and surface water remained isolated with little provision in WSP for integrated management. This effectively stymied local water users in their desire for conjunctive management. Similarly, in Arizona, the failure of state law to recognise the hydrologic connection between ground and surface water effectively excluded different forms of conjunctive management in local jurisdictions outside of active management areas.

The importance of institutional recognition in facilitating conjunctive management was evident across other case studies, as well. There were examples of legal frameworks accommodating conjunctive management, be it through rights of participation in courts and legal recognition of augmentation plans and integrated management plans (United States), or policies that integrate resource management through conjunctive rules, a willingness of government agencies to work with water users groups and agreements tailored to different exchanges between water uses (Spain).

Beyond these pre-conditions, there are lessons about the challenges confronting the ongoing management of conjunctive use. While conjunctive management has the capacity to adapt to changing biophysical circumstances and societal demands, this was not always assured in the case studies. For example, it is apparent that conjunctive management struggles to accommodate a comprehensive suite of environmental issues – this is an issue that legislatures and government agencies need to progress further. This remains an issue in the Unites States, in particular in Arizona, where there has been little progress coordinating the use of hydrologically connected groundwater and surface water to advance the protection of rare riparian habitat. Similarly, in Australia and Spain, much work remains to be done to effectively manage the impacts on groundwater dependent ecosystems and establish environmental water requirements. Entrenching consideration of environmental issues within conjunctive programs is accordingly an area that demands policy attention.

Another obstacle to effective conjunctive management was a lack of meaningful engagement of water users in integrated water decision-making and implementation. In NSW, Australia, opportunities to incorporate local water users' knowledge, preferences and ideas relating to conjunctive management and connectivity were stymied by limited consultation, the provision of overly complex data and an inability of government and users to reach agreement. This contrast with Catalonia, Spain, where the political voice and representation of users was better able to contribute a common vision in support of conjunctive management. Meanwhile, the complete exclusion of surface water rights holders, recreationists and environmentalists from the regulation of groundwater outside of active management areas in Arizona, the United States, has undermined broader conjunctive management processes.

Overcoming this obstacle will require institutional settings that better facilitate water users participation in conjunctive management decision-making. While much will depend on context, a range of successful examples from the case studies include commission/taskforces/advisory committees in Nebraska, open court processes to those who hold water rights in Colorado, the use of modelling programmes to generate better comprehension by users of the range of alternatives and harnessing well-organised groundwater user groups to act as interlocutors with the government decision makers in Jucar.

In conclusion, conjunctive management through collective action remains a 'work in progress' across the case studies. While there are some encouraging green shoots appearing in a range of international jurisdictions, notably in terms of policy, legislative and regulatory recognition of groundwater and surface connectivity and integrated management, as is often the case, difficulties arise in effective delivery. Certainly, the presence of a 'crisis' can motive institutional actors, providing of course they have the necessary tools and resources. The greatest challenge is, however, how to effectively engage a broad suite of actors, particularly water users on the ground, to deliver conjunctive management through genuine collective action.

## References

Aiken D (1999) Balancing endangered species protection and irrigation water rights: the Platte River cooperative agreement. Great Plains Nat Res J 3:119–158

Andreu J, Capilla J, Sanchis E (1996) Generalized decision support system for water resource planning and management including conjunctive water use. Great J Hydrol 177:269–291

Andreu J, Sahuquillo Herráiz A, Solera A, Pulido Velázquez M, Pulido Velázquez D, Paredes Arquiola J (2010) Ejemplo de gestión conjunta de aguas subterráneas y superficiales: la cuenca del Río Mijares. Paper presented at AEUAS, Garantías de la gestión de aguas subterráneas: diagnosis de la situación, Vila-Real, 4 Nov 2010

Arizona Water Banking Authority (2013) Background. http://www.azwaterbank.gov/Background. Accessed 18 June 2013

Baldwin C, Poh-Ling T, White I, Hoverman S, Burry S (2012) How scientific knowledge informs community understanding of groundwater. J Hydrol 474:74–83

Blomquist W, Schlager E, Heikkila T (2004) Common waters, diverging streams: linking institutions and water management in Arizona, California and Colorado. Resources for the Future, Washington, DC

Bradley J (2011) Conjunctive water management. Available via DNR. http://dnr.ne.gov/IWM/Reports/ConceptualDesignConjunctiveMgmt_032811.pdf. Accessed 18 June 2013

Bricknell S (2010) Environmental crime in Australia. Australian Institute of Criminology, Canberra

Brodie R, Sundaram B, Tottenham R, Hostetler S, Ransley T (2007) An adaptive management framework for connected groundwater-surface water resources in Australia. Bureau of Rural Sciences, Canberra

Colby B, Jacobs K (eds) (2007) Arizona water policy: management innovations in an urbanizing, arid region. Resources for the Future, Washington, DC

Cowan J (2012) Physical and legal influences on groundwater. Available via Water. http://water.state.co.us/DWRDocs/Reports/Presentations/Pages/AtoZPresentations.aspx. Accessed 18 June 2013

Dillon P, Pavelic P, Page D, Beringen H, Ward J (2009) Managed aquifer recharge: an introduction. Waterlines report no 13, National Water Commission, Canberra

Dillon P, Toze S, Page D, Vanderzalm J, Bekele E, Sidhu J, Rinck-Pfeiffer S (2010) Managed aquifer recharge: rediscovering nature as a leading edge technology. Water Sci Technol 62 (10):2338–2345

Evans WR, Evans RS, Holland GF (2012) Conjunctive use and management of groundwater and surface water within existing irrigation commands: the need for a new focus on an old paradigm. Thematic paper, Global Environment Facility, GEF ID 3726. Available via Groundwater Governance. http://www.groundwatergovernance.org/fileadmin/user_upload/groundwatergovernance/docs/Thematic_papers/GWG_Thematic_Paper_2_01.pdf. Accessed 10 May 2014

Ferrer J, Garijo L (2013) Mercados del agua y flexibilización del marco concesional (Confederación Hidrográfica del Júcar). Paper presented at XI Seminario Nacional Transparencia y concesiones, Observatorio del Agua de la Fundación Botín, 17 Jan 2013

Flores Montoya F (1998) Ventajas del aprovechamiento conjunto de aguas superficiales y subterráneas: el ejemplo de Madrid. In: Fernández Rubio R, Sánchez Fernández JA, López Camacho B, López Geta JA (eds) Aguas subterráneas y abastecimiento urbano. ITGE, Madrid

Freeman D (2010) Implementing the Endangered Species Act on the Platte Basin water commons. University Press of Colorado, Boulder

Gardner A, Bartlett R, Gray J (2009) Water resources law. LexisNexis, Chatswood

Garduño H, Foster S, Nanni M, Kemper K, Tuinhof A, Koundouri P (2010) Sustainable groundwater management: concepts and tools, GW-MATE Briefing note series; World Bank gestión sustentable del agua subterránea. Conceptos y herramientas; Serie de notas informativas Nota 10. World Bank, Washington, DC.

Getches D (2008) Water law in a nutshell, 4th edn. West Publishing, St Paul

Glennon R (1995) Coattails of the past: using and financing the central Arizona project. Arizona State Law Rev 2(2):667–756
Glennon R (2002) Water follies. Island Press, Washington, DC
Godden L, Foerster A (2011) Introduction: institutional transitions and water law governance. J Water Law 22:53–57
Gray J (2010) Water trading and regulation in Australia. In: Saddy A, Linares Martínez A (eds) Dereito das infraestructuras: Um estudo dos distintos mercados regulados. Lumen Juris, Rio de Janerio, pp 753–792
Gray J (2012) The legal framework for water trading in the Murray-Darling Basin: an overwhelming success? Environ Plan Law J 29:328–349
Harnsbarger R (1984) Nebraska water law and administration. Butterworth Legal Publishers, Austin
Holley C, Sinclair D (2011) Collaborative governance and adaptive management: (mis) applications to groundwater, salinity and run-off. Aust J Nat Resour Law Policy 14(1):37–69
Holley C, Sinclair D (2012) Compliance and enforcement of water licences in NSW: limitations in law, policy and institutions. Aust J Nat Resour Law Policy 15(2):149–189
Holley C, Sinclair D (2013a) Non-urban water metering policy: water users' views on metering and metering upgrades in NSW. Aust J Nat Resour Law Policy 16(2):101–131
Holley C, Sinclair D (2013b) Deliberative participation, environmental law and collaborative governance: insights from surface and groundwater studies. Environ Plan Law J 30(1):32–55
Holley C, Gunningham N, Shearing C (2011) The new environmental governance. Earthscan, Abingdon
Howe C (2002) Policy issues and institutional impediments in the management of groundwater: lessons from case studies. Environ Dev Econ 7:625–641
Between the Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia, the Australian Capital Territory and the Northern Territory (2004) Intergovernmental Agreement on a National Water Initiative (IANWI). Canberra
Kelly B, Merrick N, Dent B, Milne-Home W, Yates D (2007) Groundwater knowledge and gaps in the Namoi catchment management area. National Centre for Groundwater Management, University of Technology, Sydney
Kenny J (2011) Platte river recovery implementation program: four years into the first increment. Available via Prairie Fire. http://www.prairiefirenewspaper.com/2011/04/platte-river-recovery-implementation-program-four-years-into-the-first-increment. Accessed 18 June 2013
Lamontagne S, Graham D, Household I, Middlemis H, Ross A (2012) Groundwater–surface water interactions: implications for water resources management. Workshop summary report, National Water Commission, Canberra
Leshy J, Belanger J (1988) Arizona law: where ground and surface water meet. Arizona State Law J 20(3):657–748
Llamas MR, Martinez-Santos P, de la Hera A (2007) Dimensions of sustainability in regard to groundwater resources development: an overview. In: Ragone S, de la Hera A, Hernandez-Mora N, Bergkamp G, McKay J (eds) Global importance of groundwater in the 21st century: the international symposium in groundwater sustainability, Alicante, 24–27 Jan 2006. National Groundwater Association Press, Westerville
Lopez-Gunn E, Llamas MR, Garrido A, Sanz D (2011) Groundwater management. In: Rogers P (ed) Treatise in water science, vol 1. Elsevier, Amsterdam/Hackensack, pp 97–127
López-Gunn E, Rica M, van Cauwenbergh N (2012) Taming the groundwater chaos. In: De Stefano L, Llamas M (eds) Water, agriculture and the environment: can we square the circle? Taylor and Francis, Leiden, pp 227–240, Available at: http://www.fundacionbotin.org/file/44920/. Accessed 10 May 2014
Millar I (2005) Testing the waters: legal challenges to water sharing plans in NSW. In: Water Law in Western Australia, conference, July 2005. Available via EDOWA. http://www.edowa.org.au/files/presentations/wliwa.Millar.Testing.pdf. Accessed 10 May 2014
National Water Commission (NWC) (2008) Groundwater position statement. NWC, Canberra
National Water Commission (NWC) (2011a) National water planning report card 2011. Australian Government, Canberra

National Water Commission (NWC) (2011b) The NWI-securing Australia's water future 2011 assessment. Australian Government, Canberra

Natural Resources Commission (NRC) (2013) Water sharing plan reviews. Available via NRC. http://nrc.nsw.gov.au/Workwedo/WaterSharingPlanReviews.aspx. Accessed 10 May 2014

Nebraska Department of Natural Resources (2006) Integrated water management planning process. Brochure, Lincoln

New South Wales (NSW) Office of Water (2013) Water sharing plans under review. Available via NSW Office of Water. http://www.water.nsw.gov.au/Water-management/Water-sharing-plans/Plans-under-review/plans-remade. Accessed 10 May 2014

New South Wales Government (NSWG) (2011) Achieving sustainable groundwater entitlements. Available via Office of Water. http://www.water.nsw.gov.au/Water-management/Water-sharing-plans/Plans-commenced/achieving-sustainable-groundwater-entitlements-program. Accessed 26 Nov 2013

O'Rourke M, Bailey A (2010) Peel valley water sharing plan, an integrated approach. In: National Groundwater conference, Canberra, 31 Oct–4 Nov 2010

Parsons S, Evans R, Hoban M (2008) Surface–groundwater connectivity assessment. A report to the Australian government from the CSIRO Murray-Darling Basin sustainable yields project. CSIRO, Canberra

Petheram C, Bristow K, Nelson P (2008) Understanding and managing groundwater and salinity in a tropical conjunctive water use irrigation district. Agric Water Manag 9(5):1167–1179

Planas JM (2010) Participación de los usuarios de aguas subterráneas en la gestión y planificación de los recursos hídricos. Paper presented at the symposium on user participation in groundwater management and water resources planning, Valladolid, 27 Jan 2010

Reisner M (1993) Cadillac desert, revised edn. Penguin Books, New York

Rica M, Dumont A, Villarroya F, Lopez-Gunn E, Rica M, Dumont A, Villarroya F, Lopez-Gunn E (2014) Whither collective action? Upscaling collective actions, politics and basin management in the process of 'legitimising' an informal groundwater economy. Water Int 39(4):520–533

Ross A (2012a) Easy to say, hard to do: integrated surface water and groundwater management in the Murray–Darling Basin. Water Policy 14:709–724

Ross A (2012b) Water connecting people adapting. PhD dissertation, Australian National University

Sahuquillo A (2009) La importancia de las aguas subterráneas (coste/uso intensivo/almacenamiento subterráneo/uso conjunto/protección acuíferos). X Programa de Promoción de la Cultura Científica y Tecnológica. Rev R Acad Cienc Exact Fís Nat (Esp) 103(1):97–114

Schlager E, Blomquist W (2008) Embracing watershed politics. University Press of Colorado, Boulder

Schlager E, Heikkila T, Case C (2012) The costs of compliance with interstate agreements: lessons from water compacts in the western United States. Publius J Federalism. doi:10.1093/publius/pjs017

Schlumberger Water Services (SWS) (2012) Namoi catchment water study independent expert interim final report. DTIRIS NSW, Orange

SKM (2011) National framework for integrated management of connected groundwater and surface water systems. Waterlines report 57. National Water Commission, Canberra

Tan PL, Bowmer K, Baldwin C (2012) Continued challenges in the policy and legal framework for collaborative water planning. J Hydrol 474:84–91

# The Social-Environmental Justice of Groundwater Governance

10

Marian J. Neal (Patrick), Francesca Greco, Daniel Connell, and Julian Conrad

**Abstract**

Groundwater is but one component of the hydrological cycle. It interacts with and is dependent on how the other components of the hydrological cycle are managed. The rationale for sharing or allocating groundwater is guided by the principle of *equitable and reasonable utilization*. There is no universal theory of justice to which we can appeal, to help us operationalise this principle to the satisfaction of all water uses and users. Often the losers in allocation decisions are marginal communities or disempowered individuals or groups, and the natural environment. This results in the emergence of a variety of social and environmental injustices, especially if the burden falls continuously on the same group or ecosystem. Social – Environmental justice is a useful lens in the arsenal of researchers, policy makers and natural resource managers that can be used to highlight the importance of a systems approach when dealing with common pool resources such as groundwater.

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A.J. Jakeman et al. (eds.), *Integrated Groundwater Management*,
DOI 10.1007/978-3-319-23576-9_10

## 10.1 Why Justice Matters in Water Governance

Water allocation is a fundamental part of water governance. It has been described as an unavoidable conflictual process because it is fundamentally a political process and it involves multiple, competing uses and users of water (Allan 2005). The scarcity of water resources, driven by anthropogenic or natural means, exacerbates an already politically sensitive process. Issues of justice arise when resources are, or are perceived to be, in short supply or when access to water resources is restricted or refused (Wenz 1988). In these situations individuals or groups are concerned about getting their fair share and arrangements are made, or institutions created, to manage, allocate and regulate the water resources in question.

This concern about getting one's fair share arises when an individual or group feel that others are either not contributing their fair share to a public good or are taking more than their fair share from a common or communal resource (Schroeder et al. 2003). In water governance this concern revolves primarily around the latter, and can (and has) resulted in winners and losers in water allocation and access. This uneven spread of benefits and burdens presents a problem because the burden of being the loser in a water sharing or allocation arrangement can impact negatively on one's livelihoods or can be detrimental to ecosystem health; and often results in some degree of discontent or even conflict. Often the losers are marginal communities or disempowered individuals or groups, and the natural environment. This results in the emergence of a variety of social and environmental injustices, especially if the burden falls continuously on the same group or ecosystem.

Groundwater resources are increasingly threatened (Chap. 2), with the recent data from the GRACE satellites depicting the rapid rate of decline in almost all the major aquifers in the arid and semi-arid parts of the world (Goldenberg 2014). The continued unsustainable extraction of groundwater is laying the foundation for more discontent and potential conflict over this resource. A recent study of international transboundary aquifers shows that 8 % of transboundary aquifers worldwide are currently stressed due to human overexploitation (Wada and Heinrich 2013).

## 10.2 Challenges of Groundwater Governance

A focus on groundwater management and allocation is important yet it must not cloud the reality that groundwater is but one component of the hydrological cycle and that it interacts and is dependent on how the other components of the hydrological cycle are managed. It also cannot be regarded from a solely hydrological perspective (Chap. 3) – it is linked to other physical systems (soils, ecosystems, oceans, and atmosphere) and importantly to related social, cultural, economic, legal, institutional and political systems (UNESCO 2012).

Successful groundwater governance is challenging because of its interdependence with these other systems. These challenges are exacerbated because groundwater is a resource hidden from view and therefore the impacts of its use are difficult to monitor and evaluate. The importance of groundwater to society is overshadowed by the more visible surface water in rivers, lakes and reservoirs, yet the majority of the world's drinking water comes from groundwater and it supports an ever increasing agricultural sector (Giordano 2009). Groundwater allocation and sharing arrangements are further complicated by scientific uncertainties (Chap. 28) – the limited capacity to quantify surface water – groundwater interactions; aquifer recharge rates; and groundwater-dependent-ecosystem responses to fluxes in groundwater quantity and quality.

The rationale for sharing or allocating groundwater can draw on a variety of principles or values that we as human beings have constructed and developed over time to underpin our decision-making processes. In water management the call for *equitable and reasonable utilization* of water resources is a common guiding principle but it demands reflection on what we mean by equity and how this translates into practice. We need to be able to articulate what principles or values we draw upon to ensure that the outcome of water sharing is considered equitable or just. And herein lies an additional challenge – there is no one correct answer; there is no universal theory of justice to which we can appeal, to help us answer this question to the satisfaction of all water uses and users.

## 10.3 Defining Justice

Justice is a concept that most people commonly associate with the legal system – justice will be served when a wrong is righted. In the ambit of ethics something is just if it adheres to the current sanctioned value discourse – the problem being of course is that there is always some disagreement on what that discourse is (Colquitt et al. 2001). The meaning of justice in the context of its role in decision-making and resource allocation is multifaceted and is described in many different disciplines. For the purposes of this chapter, a brief examination of the trends of justice research in the social psychology literature helps define the concept.

In the 1960s and 1970s much of the justice literature assumed that people's sense of justice was concerned with the distribution of outcomes or resources based purely on motivations of self-interest (Skitka and Crosby 2003). Equity theory provided the prominent distribution or outcome orientated viewpoint. Equity is achieved according to Adams (1963) when a person's rewards or outputs are perceived to be in proportion to that person's inputs or contributions. In other words equity is affected by what is termed the contributions rule (Leventhal 1976), where a person who contributes greater should receive higher rewards or outputs.[1] There were some challenges to this mainstay theory. Deutsch (1975) introduced two additional rules that determine how rewards or outputs could be

[1] It is assumed that the use of terms 'equity' and 'equitable' in many water laws, regulations and strategies do not intend to use it in this narrow sense but rather in a broad justice sense– this however does contribute to some of the confusion over the use of term and its implications for water allocation.

distributed, these are the needs rule, where a person who has a greater need should receive higher rewards or outputs; and the equality rule, where everyone should receive equal rewards or outputs regardless of their needs or contributions. Equity (or contributions), needs and equality are rules that are used to determine how resources or rewards could be distributed. They are often referred to in the literature as the distributive justice rules.

These 'rules' however all focus on the distribution of outcomes or allocation of resources. During the late 1970s and 1980s research shifted from distribution to procedural issues. Thibaut and Walker (1975) (and Deutsch and Leventhal) expanded the notion of justice to include not only distribution rules but also procedural rules. They contend that the manner or procedures in which the allocation of rewards or outputs are decided is also critical for determining what is just. The main premise of procedural justice is that the output or final distribution of resources is more likely to be accepted as just or fair[2] if the manner in which the decision was made is deemed to be just or fair by the affected parties. In the 1980s and 1990s, since Thibaut and Walker's initial ideas on procedural justice, many more facets of procedural justice have been posited as important to defining procedural justice. They include *inter alia* the need for consistency, accurate information, opportunity to correct decisions, representation of all affected parties, interpersonal behaviour, articulation of reasons for allocation decisions, accountability and treating affected parties with respect (Brockner and Wiesenfeld 1996; Gross 2011).

Distributive and procedural justice provide some insight into the complexity of defining and understanding justice especially in the context of water resources governance where both distributional and procedural rules apply. If however we delve a little deeper into the literature, the concept of justice becomes even more textured and layered. There are many models of justice which attempt to provide an underlying or unifying explanation of why we make the decisions we do, and how we *should* make decisions in specific contexts. This Holy Grail – that there exists a unifying theory of justice – has not yet materialised, and is unlikely to in the near future (Wenz 1988). The reality is that there are many competing principles or perspectives of justice that can be used to make convincing arguments for the advocacy of quite contrary positions.

There is an extensive history and array of research that has contributed to the development of the many theories of justice; and a wide ranging review would not be appropriate for the purpose of this chapter. The aim here rather is to present a brief overview that provides sufficient background on the range of existing justice theories but also focuses on some that are relevant to groundwater governance. Bearing this in mind, four families of theories are described in Table 10.1: they are an economic family, a rights-based family, a social family and an environmental family. The description of each theory is a summary adapted from Wenz (1988) who provides a more detailed overview of a number of models and theories of justice.

[2] The terms fair or fairness is often used in the social psychology literature rather than the terms just or justice – in this chapter they are considered synonymous and are used interchangeably.

**Table 10.1** A non-exhaustive summary of the various justice theories, principles and models (Adapted from Wenz 1988)

| | | |
|---|---|---|
| The economic family | Efficiency is the driving force behind this family of justice theories where maximising surplus is advocated. This family is represented by the following: | |
| | *Libertarian theory* | Provides an underlying rationale for settling all issues of justice through the free market (and the courts). People have the right to be able to buy and sell whatever they want so long as they don't use force or fraud |
| | *Efficiency theory* | Is similar to libertarian theory in that it advocates a free market where there is a minimal State that protects private property but does not interfere with the economy. It differs in the means to achieving this goal in that it advocates maximum efficiency rather than the right to liberty and private property as its central tenet |
| | *Cost-benefit analysis* | Although a technique rather than a theory, cost-benefit analysis is often used in decision making. It is underpinned by the principles of Efficiency and Utilitarian (see below) theory. CBA analyses alternative courses of action based on the costs and benefits (primarily expressed in monetary terms) associated with each, and recommends the option with the greatest benefits and/or lowest costs as the most desirable choice |
| The rights-based family | | |
| | *Human rights* | Provides a means of settling disputes by appealing to fundamental human rights. These comprise negative rights which are rights to non-interference (e.g. people's life, liberty, expression, religion or property) and positive rights which are rights to assistance (e.g. health, education and wellbeing). In 2010 the UN General Assembly amended the Declaration of Human Rights to include the right to water and sanitation as a human right (UN 2010) |
| | *Animal rights* | Provides a means of settling disputes by appealing to fundamental animal (or non-human animal or subjects-of-a-life) rights. Animal rights comprise negative rights such as right to life and freedom, and apply to wild animals. In most countries positive animal rights only come into play when dealing with domesticated animals |
| The social family | These theories generally reflect a concern for the welfare of society. Two of the most popular and well known theories are: | |
| | *Utilitarian theory* | Provides a rationale for making decisions, taking action and designing policies that produce the greatest good. This theory supports decisions that maximise happiness or preference satisfaction, and is laudable in its aim to improve the wellbeing of all people |
| | *Rawls' theory of justice* | Rawls offers a hybrid theory that reconciles the consideration of rights and utility. The basic premise of the theory is that decisions can be made based on which alternatives offer the most help for the worst off or that the worst possible outcome is made as good as it can be. Thus decisions are made on principles that are considered fair for everyone without any prejudice |

(continued)

**Table 10.1** (continued)

| | | |
|---|---|---|
| The environmental family | These theories focus on ecosystem and environmental concerns, values and/or rights; and shine a light on the need to take the environment into account when making decisions about natural resource management and allocations; they are important when sustainability issues are taken seriously | |
| | *Biocentric individualism* | Is not a justice theory per se, but is a perspective that contributes to the discussion. It is based on the belief that there is value in every living thing and that people have an obligation to take this value into consideration whenever their actions affect living things |
| | *Ecocentric holism* | Is a view that people should limit their activities out of concern for the continued existence of a species and the continued health of ecosystems. It is also not a theory per se, but offers an additional view point that considers the broader environment in decision making |
| | *Precautionary principle* | Often referred to when development has the potential to impact negatively on the environment. Where there is a risk of irreversible harm or damage, the absence of evidence cannot be used as a reason to proceed with development |

The array of rules, theories and principles that can be called upon in order to determine on what basis water resources can be shared and allocated between users is vast and not only are they used in the allocation context, they are also used in determining who should be included or count as a potential water user and who is not, before any discussion on water allocation and access is initiated.

## 10.4 Why Justice Should Be Considered in Groundwater Governance

Even though justice is a complex, nebulous concept, it is imperative to give it due consideration since the consequences of not doing so can undermine the best groundwater management intentions. By articulating the practical meaning of equitable distribution of resources, the concept of justice also serves to illustrate the importance of a systems thinking approach when developing groundwater management plans or when managing conflict over scarce water resources.

The following case studies highlight the importance of considering groundwater as part of an inter-dependent web of systems, and the necessity of including local communities and the environment in the decision-making and allocation process in order to avoid or ameliorate potential social and/or environmental injustices.

**Case Study 1: The Daly River, Northern Territory, Australia**

Hydrological systems of the Northern Territory in Australia are currently the subject of a national debate about whether they should be used to support the expansion of irrigated agriculture in that region. A central focus is the Daly River catchment just south of Darwin. During the dry season it is one of the few rivers with flow. The Daly system does not have potential sites for large dams, therefore any expansion of irrigation would need to be based on withdrawals from groundwater or directly from the river itself which is sustained during the long dry season by groundwater inflows originating upstream. These groundwater systems currently support a mosaic of many dependent ecosystems with high biological diversity. They would be severely impacted if irrigation development goes ahead as proposed (Blanch et al. 2005).

When irrigation is supplied by releases from dams or directly from surface runoff it is usually the case that the greater the volume of extractions the more intense will be the impacts on the environment. With groundwater dependent ecosystems in the Northern Territory this pattern is reversed (DNREA 2006). It often takes only a relatively small level of extraction for the groundwater table to no longer intersect with the low lying parts of the land surface where it previously created permanent and semi-permanent wetlands. This can transform a landscape with many wetlands into a dry dusty semi desert (Blanch 2004).

The Daly River catchment includes the town of Katherine, the fourth largest in the Northern Territory and Pine Creek both with substantial Indigenous populations as well as Nauiyu, a wholly Indigenous community (Fig. 10.1). There are at least


**Fig. 10.1** Location of Daly River catchment, Northern Australia

ten Indigenous language groups in the region. The current landscape with its many wetlands is of great cultural significance to the Indigenous peoples of the region. Indigenous people make up about 25 % of the population of the Northern Territory and manage more than 30 % of its area.

In addition to the threats from proposals for future development the clear waters of the Daly River are already under pressure from current agricultural and pastoral activities that are causing increased sedimentation. High levels of water clarity are needed to support the growth of aquatic plants such as *Vallisneria nana* – the key food source for pig-nosed turtles. A very significant species for the local Indigenous communities, this species of turtle is found in only a few rivers in Australia and Papua New Guinea. It is highly vulnerable because of its nutritional dependence on this single food source and its unusual breeding process. The favoured nest sites are fine sand riverine banks in the middle and lower reaches of the Daly River. Turtles rely on warm water discharged from springs to keep warm. During reproduction the females rarely move from these places. The sex of young turtles is determined by the temperature of the water within which they hatch. If water levels are reduced due to water extraction for irrigation, nests may dry out earlier and become hotter thereby reducing the percentage of males which only hatch in cooler nests (Blanch et al. 2005).

Indigenous interests in water are a complex mix of culture and economics, the latter term covering everything from traditional activities such as hunting, fishing and gathering wild plants to eco-tourism and to irrigated agriculture. The National Water Initiative (NWI) approved by the Council of Australian Governments in 2004, placed a very high priority on the need to take account of Indigenous interests in water planning and management. However, the NWI was frustratingly vague about how that should be done and some of its elements make it hard to achieve change. For example, the separation of entitlements to water from titles to land in order to promote water trading creates a serious challenge because it undermines the Indigenous conception that land and water are integrally connected. According to Jackson (2004), Indigenous interests do not translate easily into Western environmental management frameworks which are based on objectification and quantification. The concept of environmental flows, especially when costed in monetary terms, is an example of this tendency to define everything in quantifiable units so that they will be easy to compare and allocate.

Drawing on a large body of research, Jackson (2005) has described a relationship between water and Indigenous people which is more complex than that of European settlers in the region. She argues that in the latter case the cultural dimension is a diffuse and poorly articulated aesthetic and emotional response that tends to be secondary to the focus on economic goals defined in monetary terms. Indigenous connections are more complex and can only be reduced to monetary values with a significant loss of cultural meaning and richness. For example Western systems give priority to land as measured and allocated to particular owners as the basic unit for natural resource management. To a limited extent Indigenous interests in land can be taken into account with this approach but developing a similar approach for water has proved difficult. Jackson et al. (2005) have argued that this is one reason why there has been greater recognition of Indigenous relations with land rather than with water and the wider ecological system (Jackson 2006). Arguably this disproportionate emphasis on land rather than on the ecosystem as a whole has led to a serious underestimation of the importance of water to Indigenous people. This is despite the commitment contained in the National Water Initiative which states that water plans must take account of Indigenous issues by making arrangements for Indigenous representation in water planning 'wherever possible' and provision for indigenous social, spiritual and customary objectives 'wherever they can be developed'. They should also include allowance for 'the possible existence of native title rights to water in the catchment or aquifer area' (National Water Commission 2004, paras 52–54). Given the long delays in implementing these commitments it is likely that land and water policy in northern Australia will be highly contested in coming years.

The proposed extraction of groundwater within the Daly River region for increased agricultural production needs to weighed against the potential impacts on the groundwater dependent ecosystems, their supporting flora and fauna such as *Vallisneria nana* and pig-nosed turtles, and most especially the fragile links with sites and species of cultural significance to the local Indigenous communities. Disregard of the interdependencies of economic, social and environmental uses of water in Daly River catchment could result in social and environmental injustices with long term impacts.

**Case Study 2: The Disi Aquifer: Saudi Arabia and Jordan**

Jordan is one of the most arid countries on earth. The residents of Amman, the capital of Jordan, receive running water twice a week (prior to 2002 it was only once a week). The majority of the population lives in the Greater Amman area in the North, an urban conglomerate which is also a final destination for refugees from Iraq, Syria and, historically, from Palestine. The Disi Aquifer lies south of Amman, between the South of Jordan and the northern part of Saudi Arabia (Fig. 10.2). The majority of the aquifer is located in Saudi Arabia. By the 1990s, Saudi Arabia was extracting nine times as much water as Jordan and in 1992 Jordan accused the Saudis of overpumping, but the Saudi government did not respond in any way to the accusation (Shapland 1997).

The Disi Aquifer (called the Saq aquifer in Saudi Arabia) is a reservoir of fossil water, 3,000 $km^2$ wide, with exploitable reserves estimated around 6,250 MCM (million cubic meters) (Foster and Loucks 2006), it has a minimal recharge such that it is considered 'non-renewable' in all major international classifications (USGS 2013). There is no bilateral treaty between Jordan and Saudi Arabia; despite that, a memorandum of understanding has long been due between the two countries, as they have so far not reached a formal agreement over the use of this shared water resource. During the 1980s and the 1990s, the Jordanian side of the overlying fields, around 10,000 ha, has been rented to agri-business companies in order to produce different export crops and, later on, also fruits and vegetables, consuming around 75 MCM/year and not paying any water fees (Ferragina and Greco 2008). When agri-business companies were granted the land in the 1980s, the concept of 'transboundary groundwater' barely existed. The agri-business companies exploiting the Disi aquifer on the Jordanian side were given incentives to exploit

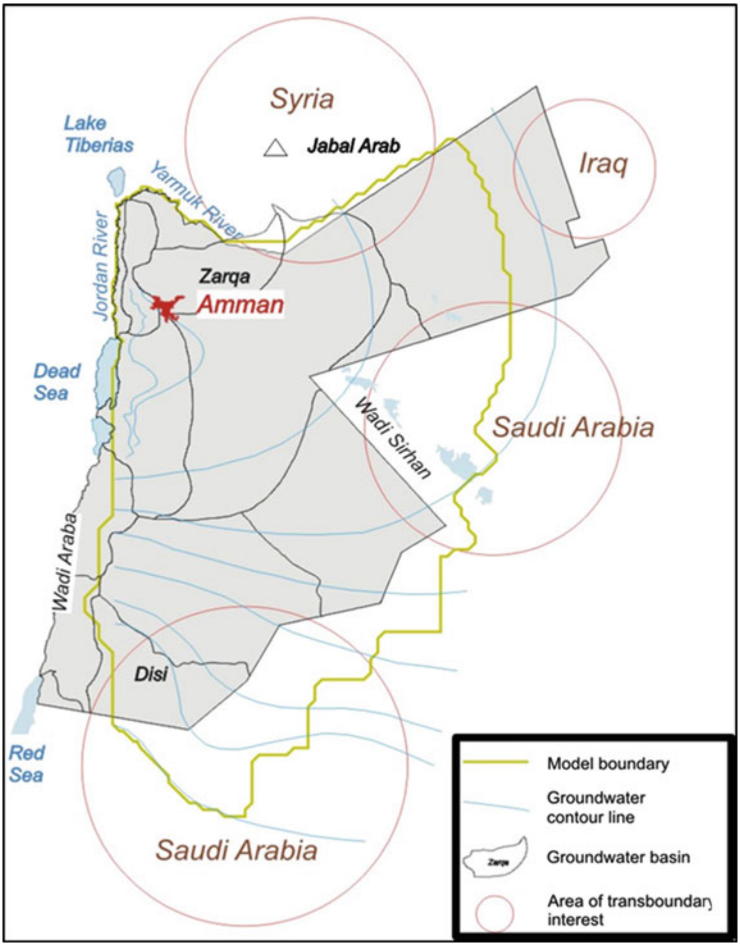


**Fig. 10.2** Location of Disi Aquifer (Source: BGR 2013)

the resource in the 1980s, this encouragement ended in recent times due to a planned alternative use of the Disi water: to supply Amman via a 350 km long pipeline. When the planning for pipeline project was initiated, the agri-business companies were given a deadline; they were to cease farming before the end of 2012, in order to stop pumping the water from the aquifer, and in order to allow the diversion of all the resources to the capital city of Amman.

The World Bank did not agree to fund the pipeline project because of the lack of a bilateral treaty between Jordan and Saudi Arabia; which was judged by the bank as a preliminary condition for the good outcome of the project. Today, the pipeline is almost completed, funded by other international lenders such as Agence Française de Développement (AFD), the European Investment Bank (EIB), the Overseas Private Investment Corporation (OPIC), and the Promotion et Participation pour la Coopération économique (PROPARCO). The main problem with this project was that it was a top-down approach, where consultation with the local populations of the desert and the Bedouin groups remained very low. The construction of the pipeline has been contested, resulting in two workers being killed by the local Bedouins, who were asserting that the project company did not include them in the economic benefits of the work in general and, particularly by not renting their trucks for transportation tasks (BBC 2011).

Social considerations regarding the rights of local people were not taken into account; they feel they do not benefit enough from the water being abstracted and brought directly to the North, and have suggested a revision of the Project Company's Environmental and Social Management Plan. The legacy of social exclusion was also evident at the time when agri-businesses were using fossil water for irrigation, in order to export crops. The rights of the local Bedouins to benefit from that water were ignored; the rights of the agri-businesses and global consumer were prioritised over the local communities. The question of 'prior use rights' for local populations of arid countries over their non-renewable water resources were raised. 'Prior use, or historical right' is internationally recognized as a tool for negotiations of international treaties and agreements among States, however a 'prior use right' cannot be established at a lower scale: at the individual level. This is why a local Bedouin from the Disi area cannot claim any prior right over a foreign citizen consuming a watermelon irrigated from the Disi. International water law is promoting the principles of 'equitable use and no harm' in the management of shared water, but only among State-entities or sub-regional institutions, not among individuals. Herein lies the problem of how to deal with 'water rights' and 'environmental justice'. There exists a gap between the meaning of justice and equity for individuals and 'equitable use' in international water law.

Another important consideration that must not be ignored is the interaction of virtual water and the Disi groundwater dispute over time (Greco 2013). If we look at the storyline of the project, the agri-business companies can be considered a "virtual water flow" exporting Disi water outside the country. This virtual water flow started when there was no concern about the transboundary nature of the aquifer, but at a later stage of analysis, it is influencing the hydro-politics of this transboundary groundwater basin. As a matter of fact, after the creation of this virtual water flow, Jordan acquired a de-facto right to pump water over Saudi Arabia. While Saudi abstractions started earlier than on the Jordanian side, the virtual water flow has changed the position of Jordan forever, in view of a possible bilateral treaty between the two countries. The allocation of the Disi water will be switched from agriculture to urban supply, thus stopping the virtual water flow. Nevertheless, the Jordanian 'acquired right', created thanks to the virtual water flow, will be a 'de-facto' situation that will play a role in any future development of a bilateral agreement between the two countries. Even if the urban supply should start in 2014 or even later, Jordan will always be in a position to claim that Disi water had been pumped by Jordan since the 1980s. This is a good example of how virtual water can alter and drive power relations in transboundary water issues and, more in general, in hydro-political complexes (Greco 2012).

Social justice, environmental justice, the impact on future generations and the threat of a sudden depletion of the aquifer are all part of this emblematic case of groundwater exploitation. As long as there is no bilateral treaty in force, no precise projection of the duration regarding the water provision for Amman, no regulation of environmental and social balance between local, national and international water-consumers, and between current and future generations, the Disi will be "pumped to the bottom", until the very last drop.

**Case Study 3: The Sandveld, Cape West Coast, South Africa**
The northern Sandveld, situated approximately 250 km north of Cape Town, consists of a coastal plain along the west coast of South Africa (Fig. 10.3). It is bordered by the Olifants River catchment in the north and east, the Berg River in the south and the Atlantic Ocean in the west. It is a sandy area comprising granular primary aquifers and deeper fractured rock secondary aquifers, with a high degree of connectivity between the aquifers. The Sandveld is primarily comprised of three parallel seasonal river systems, namely the Jakkalsvlei River, the Langvlei River and the Velorenvlei, as well as a number of smaller systems. The catchments drain westwards through the Sandveld and consist of a combination of rivers, pans and wetland systems. The Ramsar designated Velorenvlei wetland system is the best known of the three systems (DWAF 2008).

The northern Sandveld (4,827 $km^2$ in area) is a rural area with extensive farming, a few towns (Lambert's Bay, Elands Bay, Graafwater, Leipoldtville, Paleisheuwel and Redelinghuis), with fishing and tourism developments along the coastline. Most of the towns, as well as all agricultural developments in the region are supported from groundwater supplies. The main agricultural activity within the study area is the cultivation of potatoes. The water balance for the area (obtained by taking into account groundwater recharge minus discharge and abstraction estimates) ranges from 4 % to 106 % (i.e. significant over-abstraction). This is supported by observed dropping of groundwater levels in this over-abstracted area (DWAF 2006).

Potato farming, primarily is under centre-pivot irrigation systems and is the economic mainstay of the coastal plain. The potato industry employs some 3,250 workers. Between 6,000 and 7,000 ha of potatoes are planted annually in the Sandveld for the production of seed potatoes, potatoes for the fresh market and potatoes for the processing industry (French fries, crisps and frozen products). To limit the carry-over of soil borne diseases a rotation of up to 5 years is specified for the production of seed potatoes. In practice, a farmer wanting to cultivate 20 ha of seed potatoes would need to clear four 20 ha circles (80 ha) and would cultivate one circle per year, moving the centre pivot to the appropriate field each year. Nearly all plantings are irrigated. Farming input costs are high and environmental and other farming conditions often pose great challenges to the farmer in maintaining a viable enterprise (Knight et al. 2007).

Most of the native vegetation, which is being cleared for the cultivation of potatoes, is described as an open semi-succulent scrub of Fynbos form intermediate between Coastal Fynbos and Succulent Karoo (Acocks 1988). The total number of centre pivots in the potato production area of the Sandveld has been calculated as 1,773 (with a combined area of 30,740 ha) using satellite imagery (2003/2004) (Knight et al. 2007). Land clearing has a significant impact on the ecology of the

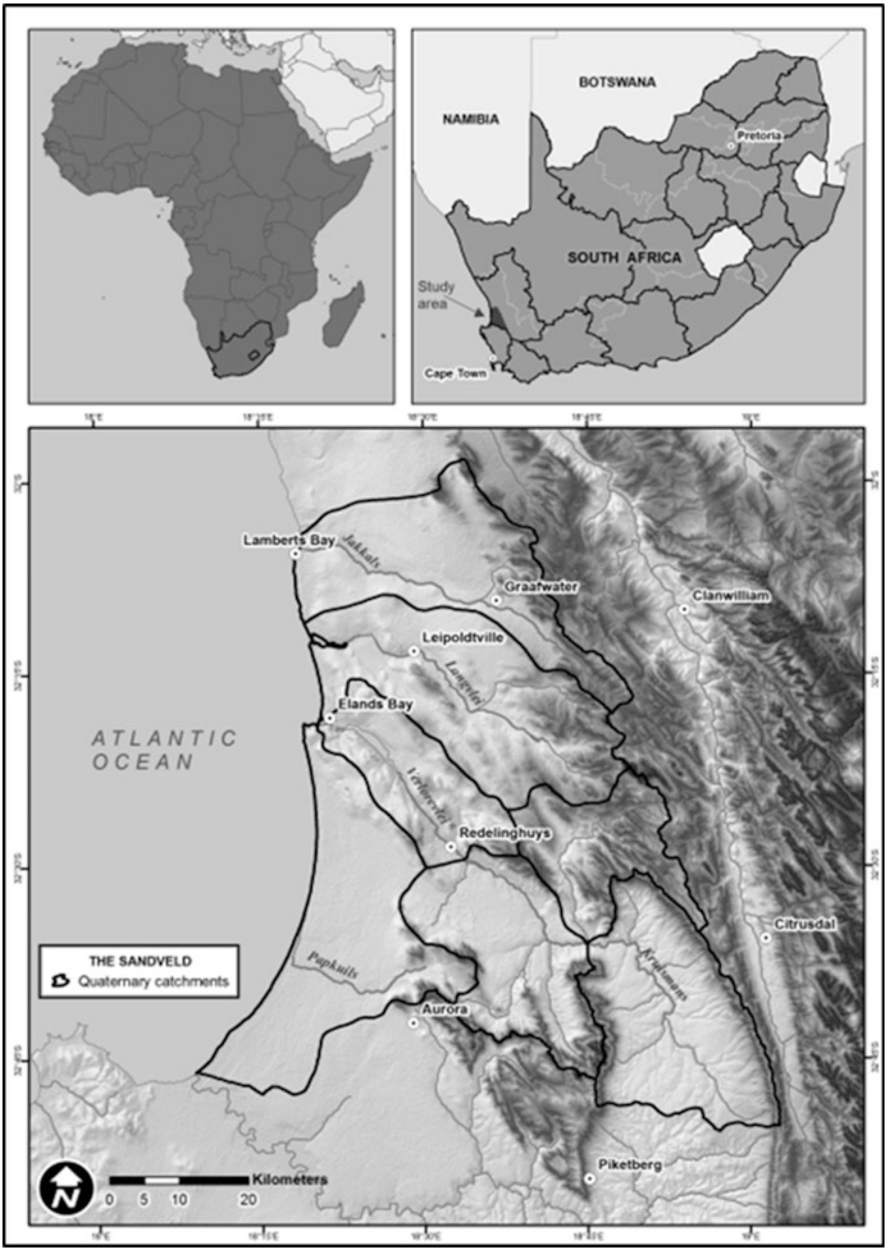


**Fig. 10.3** Location of Sandveld, South Africa

area because once the land is cleared it will never recover to its natural state. Based on broad water balance calculations for the northern Sandveld (which vary from year to year), approximately 64 $Mm^3/a$ is received as groundwater recharge from precipitation; the amount of groundwater required for full ecological functioning is ~29 $Mm^3/a$, the volume of groundwater abstracted for irrigation is ~51 $Mm^3/a$ and the volume of groundwater abstracted for municipal supply equates to ~1 $Mm^3/a$. Thus it is evident that the agricultural abstraction impacts significantly on the ecological functioning of the area. It has been observed that certain wetlands have desiccated, certain spring flows have reduced, groundwater levels have dropped in places with an associated deterioration in groundwater quality and in one area salt water intrusion has occurred. These impacts are particularly noticeable at the lower end of the catchments where production boreholes are too closely spaced (and typically where groundwater is abstracted for multiple purposes e.g. town supply and agricultural needs).

The intense development of good to marginal quality groundwater in coastal aquifers makes the water resources vulnerable to long-term over-abstraction and the intrusion of poor quality groundwater and/or seawater. Proper resource assessment, abstraction plans and monitoring is crucial for sustainable use of groundwater in these coastal areas, where agricultural interests in the catchment must also be served.

There have been many initiatives to address and protect the long term viability of the resource. Some of them include: Environmental Water Reserve studies have been completed and approved; Water User Associations have been established; monitoring is being continued in the area and a Sandveld Integrated Water Resource Management (IWRM) Plan (that will give clear guidance on the way forward for an equitable and sustainable use of the water resources within the area), has been developed. In addition the umbrella organisation of the potato industry, Potatoes South Africa, has invested in the long term monitoring of the impacts of the potato agriculture on the groundwater resources of the Sandveld. The importance of responsible groundwater use has been emphasized to the farmers within the area and there is an increased awareness of the importance of groundwater and its conservation. The northern Sandveld is a complex area where social, economic and environmental water needs are all inter-dependent and a careful balance is required to meet all the demands on the water resources of the area to ensure its long term viability.

## 10.5 Synthesis

The case studies described above illustrate how the natural environment in general and the groundwater resource in particular underpins a broad range of social, political and economic activities, and why it is important to act cautiously when exploiting a resource with many unknowns, most especially unknown extraction limits before negative ecological impacts ensue. In both the Disi Aquifer and the Sandveld case studies it is apparent that the long term prospects of the social and economic activities will be undermined if there is no due consideration for the environmental limits of the underpinning groundwater resource. Not only are there direct injustices caused by environmental degradation and reduced groundwater for subsistence agriculture, but the injustices can also spill out of the environmental and social domain into the economic domain and impact on the long term sustainability of large agro- producers and exporters. In other words 'the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987) is threatened.

The social dilemma posed by water allocation decisions centres on who or what use should get priority and in what circumstances. In the Daly River case study the dilemma is whether water should be distributed for environment and cultural uses or for irrigated agriculture. In the Disi Aquifer case study the allocation dilemma has arisen because of a change in allocation rules; initially the rationale for allocation was primarily economic driven but now increasing social demands (urban water use) is shifting the priority of use and is causing problems. The distributional dilemma can also be framed as one of long term vs short term, illustrating how important the temporal aspect is in justice considerations; for the Disi and the Sandveld it is a case of long term environmental sustainability of the resource vs the shorter term economic activity of irrigated agriculture.

The process of inclusion and exclusion of certain stakeholders or interests has been examined in the justice literature and falls within the discourse of procedural justice and public participation. Susan Opotow explores it in the context of environmental conflicts and has termed it the scope of justice (Opotow and Weiss 2000). The scope of justice, also known as the scope of moral exclusion, has been defined as the psychological boundary for fairness (Opotow and Weiss 2000) or the boundary within which justice is perceived to be relevant (Hafer and Olson 2003). Principles of justice govern our conduct towards those within our scope of justice, while moral exclusion rationalises the denial of those outside our scope of justice (Opotow and Weiss 2000) and thus enables and rationalises the application of justice principles (such as those described in Table 10.1) in an inconsistent or even in an unjust manner. In the Disi case study groundwater resources are being mined – this is old water i.e. a non-renewable resource – the significance of this fact and future environmental interests are not taken into account or included within the scope of justice. In addition the local communities' interests are not taken into account – i.e. not included in the scope of justice – therefore there are problems arising because procedural justice rules haven't been adhered to. In the Sandveld case study all interests have been taken into account – social inclusion and procedural justice issues are considered; the justice question here centres on whether long term needs vs short term gains will take priority.

Each case study has a number of proponents that will construct their argument for why they believe they should receive priority of water use from the families of justice outlined in Table 10.1 –the ultimate question is which one makes the case that will result in just and equitable outcomes and more importantly where the burdens of the unjust outcomes will fall if social and environmental justice is not the overarching goal.

## 10.6 Joining the Dots: Justice, Governance and Sustainability

Water governance can be defined as a system for managing water according to objectives that reflect the goals of society. This system includes various organisations such as government departments, non-government organisations and civil society groups, and a range of institutions such as principles, policies, regulations, legislations and social norms that operate at a variety of levels (Ashton et al. 2005; North 1990). As environmental discourses and water management paradigms have evolved, so too have the structure and mandate of water governance systems.

The link between sustainability and justice has been explored at the conceptual level and has been termed *Just Sustainability* by Agyeman (2005a, b). *Just Sustainability* is best described by briefly recapping the origins of both environmental justice and sustainability. Environmental justice rose to prominence shortly after the civil rights movement in the United States of America and focused on the locating of toxic waste sites in close proximity to minority residential communities. Rallying around this and other forms of environmental racism led to the emergence of grassroots activism that protested against development and policy that did not embrace the principle that all people and communities are entitled to equal protection under environmental and public health laws and regulations (Towers 2000). The definition and scope of environmental justice has evolved since this initial movement around local environmental hazards and is now widely acknowledged and understood by many environmental justice organisations to include broader social justice considerations (Agyeman and Warner 2002). It does however run the risk of focussing too narrowly and solely on the community level in finding solutions to injustices.

The concept of sustainability emerged from the opposite end of the spectrum – a global rather than a grassroots phenomenon. Although its beginnings pre-date the 1972 United Nations Conference on the Human Environment in Stockholm, sustainable development was popularised through this event; and then progressively mainstreamed into our collective consciousness and policies through the 1983 World Commission on Environment and Development and the subsequent publication of *Our Common Future* in 1987; the 1992 World Summit in Rio de Janeiro and the publication of Agenda 21; the 2002 World Summit for Sustainable Development in Johannesburg and the publication of the Plan of Implementation, and lastly the 2009 World Conference on Education for Sustainable Development held in Bonn and the publication of the Bonn Declaration. Sustainable development emerged as a response to the recognition that many of the environmental problems that we currently face are now manifest at a global level and that individual Nation-States or a piecemeal response to these problems would be unsuccessful in addressing them. Sustainability has now become a “higher order social goal” (Dovers 2005, p. 8). It aims to address the bigger picture but it can potentially lose sight of the social justice dimension of meeting the needs of current generations.

One of the major tensions between the two concepts is scale related. Environmental justice claims are often initiated at the local – grassroots – community level, while calls for sustainability are usually more strategic in nature and are often initiated at the regional, national or international level. The proponents of sustainable development have recognised the conflict between the need for an overarching vision and the practical implementation of action plans at a more local level through the Local Agenda 21 programme and the Johannesburg Plan of Implementation; but there is still continuing and growing poverty and environmental degradation. This tension presents an opportunity for synergy between the two concepts – the strengths of one make up for the weaknesses in the other. It is clear that there exists an imperative to include justice issues into the higher social goal of sustainability, but it cannot be achieved if there is a perpetuation of social exclusion, be it racism or classism, or the exclusion of any other social, economic or environmental voice. Agyeman suggests this revised rationale for sustainability: "The need to ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems" (2005b, p. 17).

## 10.7 Conclusion

Social – Environmental justice is a useful lens in the arsenal of researchers, policy makers and natural resource managers that can be used to highlight the importance of a systems approach when dealing with common pool resources such as groundwater – it can highlight the inter-connectedness of systems and the potential social, economic and environmental consequences of disregarding this inter-dependency.

Three important and necessary questions that a justice perspective offers that are likely to improve groundwater governance if answered include:

1. What underlying 'rules' have been used to make a water allocation decision. Have both distributional justice and procedural justice rules been taken into account?
2. Which justice theory, model or principle has been used as the rationale for how the water resource is shared? Does the underlying rationale draw from the economic, social, rights-based or environmental family of justice theories (or a combination of families) and how does this potentially influence the outcome?
3. Who or what has been included and excluded from the scope of justice or scope of the decision-making process and for what reasons?

It is important to be explicit about answering these challenging questions because if the social, political, economic and environmental aspects of groundwater management are not taken into account, this could and has led to reduced groundwater levels to such an extent that sites of cultural significance are lost, local and small scale subsistence farmers have no access to water, tensions between countries might arise over shared water resources, native biodiversity is lost and the long term investment in commercial agriculture is threatened.

## References

Acocks JPH (1988) Veld types of South Africa, 3rd edn. Memoirs of the botanical survey South Africa no 28. Government printer, Pretoria

Adams JS (1963) Toward an understanding of inequity. J Abnorm Soc Psychol 67:422–436

Agyeman J (2005a) Sustainable communities and the challenge of environmental justice. New York University Press, New York

Agyeman J (2005b) Where justice and sustainability meet. Environment 47:10–26

Agyeman J, Warner K (2002) Putting 'just sustainability' into place: from paradigm to practice. Policy Manag Rev 2:8–40

Allan JA (2005) Water in the environment/socio-economic development discourse: sustainability, changing management paradigms and policy responses in a global system. Gov Oppos 40 (2):181–199, Blackwell Publishing, Oxford

Ashton PJ, Patrick MJ, Mackay HM, Weaver A (2005) Integrating biodiversity concepts with good governance to support water resources management in South Africa. WaterSA 31:449–456

BBC (2011) BBC monitoring Middle East. BBC, London. http://search.proquest.com/docview/822342242. Accessed July 2013

BGR (2013) Groundwater basins and transboundary aspects in Jordan. www.bgr.bund.de. Accessed June 2013

Blanch S (2004) Submission-in-progress to the water allocation plan for the Daly region. World Wildlife Fund for Nature Australia, Darwin

Blanch S, Rea N, Scott G (2005) Aquatic conservation values of the Daly River catchment Northern Territory, Australia. A report prepared by World Wildlife Fund. Charles Darwin University, and the Environment Centre NT, WWF Sydney, Sydney

Brockner J, Wiesenfeld BM (1996) An integrative framework for explaining reactions to decisions: interactive effects of outcomes and procedures. Psychol Bull 120:189–208

Colquitt JA, Conlon DE, Wesson MJ, Potter COLH, Yee Ng K (2001) Justice at the millennium: a meta-analytic review of 25 years of organisational justice research. J Appl Psychol 86:425–445

Deutsch M (1975) Equity, equality, and need: what determines which value will be used as the basis of distributive justice? J Soc Issues 31:137–149

DNREA (2006) Conjunctive water management and Northern Territory water policy. Department of Natural Resources, Environment and the Arts, Northern Territory. www.connectedwater.gov.au/water_policy/nt_persepective.html. Accessed Dec 2006

Dovers S (2005) Environment and sustainability policy: creation, implementation, evaluation. The Federation Press, Sydney

DWAF (2006) Groundwater reserve determination for the Sandveld, Olifants-Doorn Water Management Area, Compilation of a high confidence ecological reserve for the groundwater, wetland and salt pan components. Consulting report for the Department of Water Affairs and Forestry. Compiled by Conrad J, and Munch Z, Pretoria

DWAF (2008) Integrated water resources management plan for the Sandveld, Olifants Doorn Water Management Area, Western Cape, Background information to management plan.

Consulting report for the Department of Water Affairs and Forestry. Compiled by Belcher A, Conrad J, and Grobler D, Pretoria
Ferragina E, Greco F (2008) The Disi Project: an internal – external analysis. Water Int 33:451–463
Foster S, Loucks DP (2006) Non renewable groundwater resources, IHP VI – series on groundwater no 10. UNESCO, Paris
Giordano MA (2009) Global groundwater? Issues and solutions. Annu Rev Environ Resour 34:153–178
Goldenberg S (2014) Why global water shortages pose threat of terror and war. The Guardian. www.theguardian.com/environment/2014. Accessed 11 Mar 2014
Greco F (2012) Adding an historical perspective to virtual water flows: hydrometabolism and the history of virtual water rivers. AAG 2013. Available at http://bit.ly/ZUcDjo
Greco F (2013) Hegemony and counter-hegemony in virtual water trade: justice for indigenous people? In: Proceeding of the 6th Hydro Hegemony workshop on transboundary water justice, London
Gross C (2011) Why justice is important. In: Connell D, Grafton RQ (eds) Basin futures: water reform in the Murray-Darling Basin. ANU E Press, Canberra
Hafer CL, Olson JM (2003) An analysis of the empirical research on the scope of justice. Pers Soc Psychol Rev 7:311–323
Jackson S (2004) Preliminary report on aboriginal perspectives on land-use and water management in the Daly River region, Northern Territory. Report to Northern Land Council, CSIRO Sustainable Ecosystems, Darwin
Jackson S (2005) Indigenous values and water resource management: a case study from the Northern Territory. Aust J Environ Manag 12(3):136–146
Jackson S (2006) Compartmentalising culture: the articulation and consideration of indigenous values in water resource management. Aust Geogr 37:19–31
Jackson S, Storrs M, Morrison J (2005) Recognition of aboriginal rights, interests and values in river research and management: perspectives from northern Australia. Ecol Manag Restor 6:105–110
Knight F, Conrad J, Helme N (2007) Biodiversity: best practice guidelines for potato production in the Sandveld. Report compiled for Potatoes South Africa and CapeNature and funded by Conservation International, Potatoes SA and Woolworths, Pretoria
Leventhal GS (1976) What should be done with equity theory? New approaches to the study of fairness in social relationships. National Science Foundation, Washington, DC
National Water Commission (2004) National water initiative. Intergovernmental agreement on a National Water Initiative Council of Australian Governments (COAG)
North DC (1990) Institutions, institutional change and economic performance. Cambridge University Press, New York
Opotow S, Weiss L (2000) Denial and the process of moral exclusion in environmental conflict. J Soc Issues 56:475–490
Schroeder DA, Steel JE, Woodell AL, Bembenek AF (2003) Justice within social dilemmas. Pers Soc Psychol Rev 7:374–387
Shapland G (1997) Rivers of discord: international water disputes in the Middle East. Hurst, London
Skitka LJ, Crosby FJ (2003) Trends in the social psychological study of justice. Pers Soc Psychol Rev 7:282–285
Thibaut J, Walker L (1975) Procedural justice: a psychological analysis. Wiley, New York
Towers G (2000) Applying the political geography of scale: grassroots strategies and environmental justice. Prof Geogr 52:23–36
UN (2010) Declaration of water and sanitation as a human right. General Assembly GA/SHC/3987. Human Rights Council. www.un.org/en. Accessed Oct 2011
UNESCO (2012) Groundwater and global change: trends, opportunities and challenges. United Nations World Water Assessment Programme. UNESCO, Paris

USGS (2013) Water data banks project, multilateral working group on water resources, middle east peace process. Overview of Middle East water resources. http://exact-me.org/overview/p12.htm. Accessed June 2013

Wada Y, Heinrich L (2013) Assessment of transboundary aquifers of the world – vulnerability arising from human water use. Environ Res Lett 8:13pp

WCED (1987) Our common future. World Commission on Environment and Development. Oxford University Press, Oxford. Available online: http://www.un-documents.net/wced-ocf.htm

Wenz PS (1988) Environmental justice. State University of New York Press, New York

# Social Justice and Groundwater Allocation in Agriculture: A French Case Study

11

Jean-Daniel Rinaudo, Clémence Moreau, and Patrice Garin

**Abstract**

This chapter focuses on the design of rules for apportioning limited groundwater resources among agricultural users. It shows that different (often antagonist) conceptions of desirable water allocation rules co-exist within the agricultural community, reflecting farmers' differences in terms of economic self-interests, historical background and ethical values. Based on an empirical case study conducted in France, we disentangle the factors which determine the acceptability of alternative groundwater allocation rules by farmers, paying specific attention to the perception of their legitimacy, feasibility and social justice. We show that social justice plays a very significant role in the construction of the acceptability judgment, as already highlighted by a series of Australian studies.

## 11.1 Introduction

Since the latter part of the twentieth century, individual irrigation based on groundwater has experienced strong development in agriculture worldwide (Chap. 2; Giordano and Villholt 2007). In many countries, including those where groundwater use is now regulated (Australia, Chile, Spain, and Western US States) groundwater use has developed within a non-constraining institutional framework which often resembled a free-access regime. Farmers were granted abstraction licenses which specified a maximum pumping capacity or an area to be irrigated, generally without imposing (or enforcing) any effective constraint in terms of volume. Public

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A.J. Jakeman et al. (eds.), *Integrated Groundwater Management*,
DOI 10.1007/978-3-319-23576-9_11

agencies in charge of issuing licenses favorably responded to farmers' demand without having accurate (if any) information, neither on the sustainable yields of the aquifers, nor actual abstractions by farmers. This resulted in groundwater overuse and related problems such as declining water tables, land subsidence, sea water intrusion in coastal aquifers, reduced river flows, springs dry-up and/or ecological deterioration of groundwater dependent ecosystems (Giordano and Villholt 2007, Chap. 2).

In many countries confronted with this evolution, in particular in the developed world, the response from policy makers consisted of a progressive shift from one of free access to a regulated abstraction regime. A review of case studies in Australia (Bennett and Gardner 2014), Spain (Ross and Martinez-Santos 2009; Garrido and Llamas 2009), Chile (Hearne and Donoso 2005), several Western States in the US (Blomquist et al. 2004; DuMars and Minier 2004; Schlager 2006) and France (Figureau et al. 2015) suggests that the establishment of regulated abstraction management regimes is a three stage process. The first one consists of imposing a status quo and characterizing the extent of the problem. No new licenses are issued, meters are installed to monitor actual groundwater use and studies are carried out to assess the sustainable yield of the aquifer. This stage can last several years, due to the time needed to conduct hydrogeological studies and political opposition from farm lobbies (denial of the problem, gap between scientific and lay knowledge, refusal to install meters, lobbying for the development of alternative resources). Time is also needed to allow for a change in prevailing mental models and the social representation of water. Indeed, as water becomes a limited resource, it takes on an economic dimension, creating incentives for private appropriation (the value of agricultural land increases if a groundwater use licence is attached to it), bringing about competition among users. In the rural world, this evolution may run against established social values (solidarity, mutual aid) and be relatively slow. The second stage corresponds to the design and negotiation with stakeholders of a new regulation framework that can theoretically ensure total abstraction does not exceed the sustainable yield. Public agencies estimate the percentage by which current water use must be reduced to align with aquifer sustainable yield. Rules for apportioning the authorized volume between sectors, then between users within each sector, are negotiated. The characteristics of the water use rights associated to individual allocation are also specified (validity period, transferability, etc.). A general approach concerning the role played by the different actors must also be stated (command and control, decentralized management involving users, market based mechanisms). The third stage consists of implementing the reform, raising many issues related to rule compliance and enforcement.

This chapter focuses on the second stage of this reform process and more specifically on the design of rules for apportioning the available volume of water among users. Not surprisingly, this is a very sensitive and often controversial step, which may impact the whole outcome of the reform process. Different (often antagonist) conceptions of desirable water allocation rules co-exist within the agricultural community, reflecting farmers' differences in terms of economic self-interests, historical background and ethical values. Crafting a groundwater allocation rule which can be accepted by the greatest possible number of farmers represents a major challenge for water managers. Indeed, a rule that would not be accepted would probably not be complied with, meaning that many farmers would abstract more than the share of water to which they are entitled. This outcome would raise the level of enforcement effort (control and sanction) required from the manager who may not be able to deliver it (public agency or water user association alike) in a context of increasingly limited human and financial resources. It would also result in increased tensions between the farming community and the administration.

One strategy for water managers to increase reform acceptability consists of performing an initial analysis of how stakeholders perceive different allocation rules, using hypothetical scenarios, before initiating any negotiation on groundwater allocation. The aim is to disentangle the factors which determine the acceptability of the different scenarios, paying specific attention to the perception of their legitimacy, feasibility and social justice (see also Chap. 10). Social justice plays a very significant role in the construction of the acceptability judgment, as highlighted by a series of Australian studies in the water sector (Syme and Nancarrow 1997; Nancarrow et al. 1998; Gross 2011). These studies suggest that an allocation rule is more likely to be accepted, together with the corresponding economic losses it implies, if users consider that the rule leads to an equitable apportionment of water resources (distributive justice) and if they consider the choice of the rule results from a fair decision making process (procedural justice) . Investigations conducted by Syme and Nancarrow have highlighted that water users construct their own definition of fairness by articulating different lay philosophies of justice. The resulting perception of what a “fair” allocation is thus varies in space and time. Consequently, since there is no dominant definition of justice, the way the notion is constructed should be assessed on a case by case basis, considering the history, economy, social organization and the prevailing ethical values of each local society as well as users’ heterogeneity in terms of social preferences.

The research presented in this chapter contributes to this field of investigation through an empirical case study conducted in five French groundwater basins. Building on the results of the Australian studies, it goes further by attempting to articulate the notions of acceptability and social justice, the latter being considered as an important, but not the sole, determinant of acceptability. The study focuses on water allocation within the agricultural sector, while most previous studies have dealt with inter-sectoral allocation. The method chosen involves eliciting farmers’ visions in regard to nine water allocation scenarios, each of which reposes one (or a combination) of a theoretical concept of social justice. The consultation, organized through semi-structured interviews, involved 76 farmers selected within the five French groundwater basins. From an operational perspective, this chapter proposes a method that is both original and readily implemented to evaluate a priori the acceptability of the different water allocation rules.

The chapter is organized as follows. It begins with a presentation of various policy approaches implemented worldwide to manage water abstraction in over-used or over-allocated groundwater basins, clarifying the underlying principle of justice. It then describes the French context, the method adopted and the case studies. Subsequently, we present the results obtained (perception of the nine scenarios), before discussing policy implications of the study.

## 11.2 Groundwater Allocation Policies and Social Justice Principle

### 11.2.1 Philosophical Conceptions of Justice

In many countries, policies consistently state that water resources need to be allocated with equity, without clearly defining how equity can actually be measured and how an equitable and fair allocation can be achieved in practice (Movik 2014; Roa-García 2014). The notion of distributive justice can indeed refer to very different interpretations and philosophical principles (Lamont and Favor 2012) such as prior appropriation or entitlement (Nozic 1974), strict egalitarianism (Nielsen 1979), the difference principle and equality of opportunity (Rawls 1971), the desert-based principle (Sadurski 1985), welfare based principles (Mill 1940) and libertarian principles (Nozic 1974).

According to the prior appropriation conception of justice, people who first use the resource are entitled to keep it (entitlements) provided they do not violate the rights of others. Strict egalitarianism assumes that all members of the society should be given access to the same amount of resources because "*people are morally equal, and that equality in material goods and services is the best way to give effect to this moral ideal*" (Lamont and Favor 2012). The difference principle assumes that inequalities in the distribution of resources are acceptable if they improve the situation of the worst-off in the society, whereas the "equality of opportunity" principle aims at attenuating inherited sources of inequalities (gender, race). The desert principle assumes that resources should be allocated considering the socially valuable efforts (i.e. leading to the production of goods and services desired by others) made by each individual. Welfare-based principles of justice assume that the allocation of resources should maximize social welfare, defined as the sum of individual satisfied preferences, and frequently interpreted in terms of economic wealth (utilitarian approach). Finally, libertarian theories assume that the allocation of resources resulting from market mechanisms is just because it results from transactions which are just in themselves; in that conception, no specific distributive pattern is required for justice, what matters is that acquisition and exchange conditions be right.

### 11.2.2 Existing Groundwater Policies and Underlying Conceptions of Justice

In practice, policy approaches which have been implemented to manage over-allocated groundwater systems frequently rely on a combination of several of the justice principles listed above. Based on an analysis of allocation policies implemented worldwide, we identify five archetypal policy approaches which we consider representative of the diversity of practices worldwide.

The first policy approach is based on the prior appropriation doctrine, based on a "first in time, first in right" philosophy. To align global abstraction with sustainable yield, the regulator curtails volumes granted to junior users while senior users do not suffer any (or a smaller) reduction. This approach implicitly considers that access to groundwater is subject to a priority order according to chronological possession. It considers individual water entitlements as property rights, valid in perpetuity, and which can be sold and purchased like any other property. Examples of such allocation policies can be found in Western States of the USA (Chap. 22; Blomquist et al. 2004; Schlager 2006).

An alternative policy approach consists of imposing on all users the same reduction in percentage of the volume they have been using during a recent reference period. It relies on two principles: an egalitarian principle, which refers to treating people identically (same cut-back in percentage), without regard to historical, social and economic circumstances; and an implicit recognition of the right to continue pre-existing use (grandfathering). The corollary is that water entitlement can be reduced when the volume specified in the license is not fully used (sleeping allocations). This reduction is undertaken without offering any financial compensation as there was no beneficial use of the corresponding volume. Policies reflecting this approach have been implemented in several Australian States (NRMSC 2002) and in the UK but also in some Water districts in the Western USA (e.g. California) who apply a "use it or lose it" condition. It remains attractive to policy makers in that it does not move too far away from the status quo, thereby minimizing political opposition to the reform and risks of social unrest during the implementation phase. Note that similar approaches have been implemented to allocate catch quotas in fisheries (Presser 1994; Khalilian et al. 2010).

A third policy approach embodies calculating the volume of water that would be theoretically needed by each farmer, assuming efficient irrigation technologies and considering the crops cultivated during a reference period. This theoretical volume then constitutes an individual reference to which the regulator applies an across-the-board cut-back to ensure sustainable use of the aquifer. Efficient farmers will thus have smaller cut-backs in allocation than others. This approach reflects a philosophy of justice based on the principle of desert or merit (those who made efforts to improve efficiency being rewarded while others are disadvantaged) and efficiency. It has been applied since the mid 1990s in a limited number of French groundwater basins.

In the three previous approaches, actual users benefit from an historical rent, whereas new users are denied access to the resource. This may result is inefficient water allocation if historical users have a low water marginal productivity as compared to new users. To solve that problem, a fundamentally different approach can be adopted to adjust allocation in over-allocated groundwater systems. It consists of cancelling all existing licenses before reallocating the available volume of water using an auction mechanism. This allows new users to enter the system while removing inefficient users. The underlying philosophy of justice is that users who maximize the added value of water, and who can pay for it, deserve using it (economic efficiency). This approach has not been used in practice, except in some Australian basins, where unused volumes of water are auctioned.

A fifth and last approach applies different allocation cut-back rates to users, depending on inherited historical equities that result in present inequitable opportunities. Reductions or no cut-backs will be imposed on farmers who have received limited water allocation due to late arrival in the zone, to inequitable past policies or to farmers affected by long lasting unfavorable market conditions. The objective is to protect economically fragile farmers who could possibly be ruled out of business with an egalitarian or an efficiency based approach, following Rawls' difference principle. In some French basins for instance, the regulator has decided to exempt small cattle breeders and certain fruit producers from seasonal allocation cut-backs, considering their high exposure to market risks. Farmers entitled with small water allocations are also exempted from cut-backs (France, Australia). The objective can also be to redress historical inequities or reduce poverty, as practiced for instance in South-Africa (Movik 2014; van Koppen and Schneiner 2014).

### 11.2.3 The Construction of Fair Allocation Policies

The five approaches described above represent archetypal policy options for managing over-allocated groundwater systems. They certainly do not represent off-the-shelf solutions that would be directly applicable in a different context. However, because they illustrate the range of possible policy options, they can be used as hypothetical scenarios for engaging a debate between stakeholders. The virtue of using such scenarios as educational material is that it compels stakeholders to clarify why they support or reject a given policy option. This debate is expected to make explicit the diversity of principles advocated within the community (in particular social justice principles) for guiding the choice of a water allocation rule. While some of the principles enunciated will be incompatible, others can be combined to construct hybrid policy scenarios likely to be accepted by the greatest number. Critical scenario analysis is also expected to highlight how each individual articulates different principles of justice to reconcile their own self-interests and philosophical values. Understanding the complexity of individual constructions of a sense of justice is seen as a key asset for the regulator seeking to engage stakeholders in a negotiation over water allocation rules. This is now illustrated through the French case study.

## 11.3 Case Study and Methodology

### 11.3.1 Context and Objective

The French situation illustrates the challenges related to the shift from an open access to a regulated groundwater abstraction regime, as described in the introduction. In France, the area irrigated increased from 1.8 to 2.7 million hectares between 1988 and 2000, mainly through the development of groundwater abstraction through private individual wells (Loubier et al. 2013). Until the mid-1990s, farmers were almost systematically granted groundwater use licenses which did not impose any ceiling on abstraction. In 1992, a new Water Act laid the foundations of a groundwater abstraction regulation regime, by imposing metering of all water uses and creating groundwater safeguard zones where government agencies could refuse granting new licenses. More sophisticated regulation regimes were experimentally introduced in a dozen basins, consisting of “capping” total water abstraction and assigning individual quotas (volume per year) to each farmer. The 2006 Water Act generalized this regulation regime to all basins characterized by over-abstraction. In these basins, hydro-geological studies were conducted to assess a sustainable yield. Government agencies calculated an available volume of water and apportioned it between sectors, priority being given to urban supply, industry then agriculture. The volume allocated to agriculture was then officially attributed to newly established Groundwater Users’ Associations (GWUA- *Organisme Unique de Gestion Collective* in French). These Associations are made responsible for apportioning it among farmers, crafting their own rules for defining individual water allocation. Given the limited resources they have to enforce these rules, they are concerned about identifying options that are more likely to be accepted and complied with by farmers.

The empirical study presented in this chapter was conducted in this context. Its first objective was to design and test a methodology that could be used by GWUAs to assess the perception of various hypothetical water allocation rules, prior to engaging stakeholders in a negotiation. The second objective consisted in checking if there were any – or a limited number of – dominant conceptions of social justice within the French farming community, which could be used to define a French water allocation ‘doctrine’, potentially usable by all GWUAs.

### 11.3.2 Overview of the Approach

The methodology of this research comprises four stages. The first involves defining water sharing rules scenarios, each one being based on one (or a combination of) concepts of justice, in line with the archetypal approaches described above. Scenarios were adapted to the French context and presented in the form of a brief text which was sent to the farmers in advance.

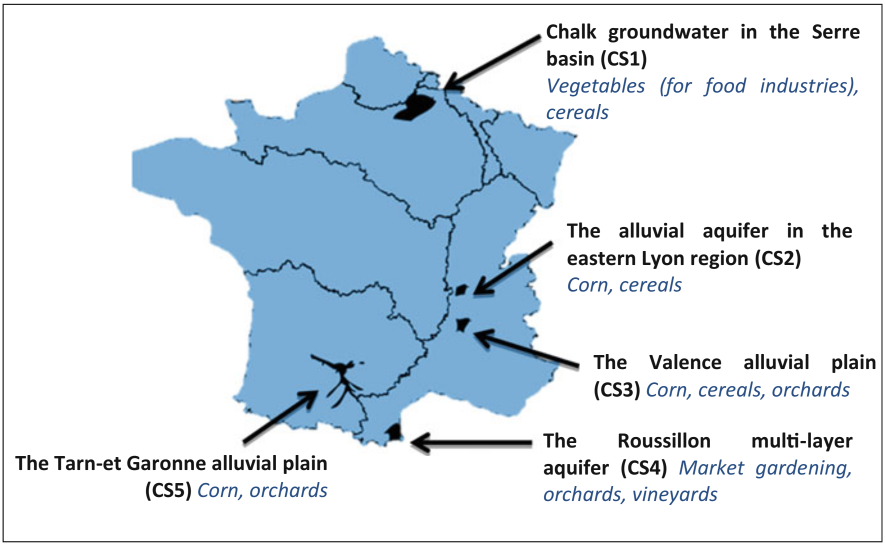


**Fig. 11.1** Location and characteristics of the terrains in the study

The second stage entailed discussing these scenarios with farmers, through interviews conducted in five different groundwater basins (Fig. 11.1), and selected based on two criteria: dependency on irrigation from groundwater; and management of water scarcity. Face-to face interviews were conducted where possible (30 interviews) but some had to be made by telephone for practical considerations (17). Discussions were tape recorded to allow subsequent detailed analysis. Twenty-nine other farmers who were contesting the legitimacy of the reform process refused to answer the questionnaire. They however all explained their viewpoint and their arguments were subsequently analyzed. For each scenario, the individual was asked to explain why they felt that the scenario was acceptable or not, and secondly if and why they would consider it as fair and equitable. At the end of the interview, the preferred scenario, or a combination of several preferential scenarios, was to be indicated.

The third stage comprised a qualitative analysis of the discourse of participants and a quantitative analysis of their answers to the questionnaire. The arguments put forward by the farmers were re-transcribed word for word and used as a starting point for a qualitative analysis of the principles underlying the various visions of social justice in the agricultural community. The fourth stage was devoted to presenting the results to farmers to obtain a validation of our analysis and additional feedback. This was undertaken through organizing a meeting in each of the case study areas and disseminating a 4-page synthesis of the results to all interviewed farmers.

**Table 11.1** Description of allocation rules and corresponding principles of justice for the nine scenarios discussed with farmers

| Description of water allocation rule | | Underlying principles of justice |
|---|---|---|
| Access restricted to historical water users | ❶ The allocation is proportional to past abstraction (last 5 years average). | Historical entitlements/ grandfathering (right to continue preexisting use) |
| | ❷ The allocation is based on usage seniority, with priority given to those whose usage dates back the furthest | Prior appropriation (original date of appropriation determines legitimacy to use water) |
| | ❸ The allocation is proportional to the declared pumping capacity of registered wells and independent of actual use | Merit (farmers who registered their wells and properly declared the pumping capacity are rewarded) + grandfathering |
| | ❹ The volume allocated per hectare is inversely proportional to the size of the farm: small farms get a greater allocation per hectare | Equality of opportunities (positive discrimination to compensate inherited inequalities) + grandfathering |
| | ❺ The allocation depends on production specialization: priority is granted to high added value crops (orchards, seeds) | Economic efficiency + grandfathering |
| | ❻ The allocation depends on soil type. Farmers cultivating soils with low water retention capacity receive a higher volume per ha, since crops grown on these soils have greater water requirements | Equality of opportunity (compensation of natural handicap) + grandfathering |
| | ❼ The allocation depends on the accessibility of alternative water supply sources. Groundwater is granted proprietarily to those who have access to no other resource (rivers, reservoirs) | Equality of opportunity (compensation of naturally unfavorable water supply situations and differentiated treatment in historical water resource development policies) |
| Access open to all farmers | ❽ The allocation is open to all farmers, whether currently irrigating or intending to do so in the 5 years to come | Equal treatment of all farmers (strict egalitarian approach), no vested rights linked to historical use |
| | ❾ All existing licenses are cancelled. The available volume of water is auctioned (highest bids get water) | Economic efficiency (maximization of economic value of water) |

## 11.3.3 The Scenarios of the Initial Allocation Rule

Nine allocation rule scenarios were used to support discussions with farmers during the interviews. Each one is implicitly based on one or several philosophies of justice, as indicated in Table 11.1 below. Two main groups of scenarios are differentiated: those of the first group all assume that only historical users can receive an allocation; whereas the second group considers that a fair allocation should provide all farmers with the possibility to access the resource, independently of historical circumstances.

This methodology is partly inspired from Syme and Nancarrow's studies in Western Australia who ask their respondents to assess a number of prominent philosophical statements (Syme and Nancarrow 1996, 1997) or water management scenarios (Nancarrow et al. 1998). Note that farmers were only provided with a detailed description of the first column of Table 11.1, expressed in lay terms.

## 11.4 Results: The Acceptability of Allocation Rules Scenarios

### 11.4.1 Sticking Points to the Approach

A first significant result is that nearly 40 % of the farmers contacted refused to evaluate the scenarios. All of them justified their positions, using several arguments which are briefly presented hereafter. First, farmers contest the legitimacy of the reform on several grounds. They challenge the reality of water scarcity and the subsequent need for establishing a rationing system. Based on their own observations, they believe that water is more abundant in their area than the experts claim, and that there is no need to reduce abstraction. They also challenge the legitimacy of the volumes of water devoted to the environment (at the expense of agriculture) and/or consider that society should subsidize the construction of new resources (dams, hillside storage reservoir) to compensate for rationing groundwater use for farming. The farmers also refute the relevance of a system of individual volumetric quotas on the grounds that it introduces a rigidity that hinders their freedom to adapt their production strategy to a changing economic context. Moreover, they consider cut-backs as a violation of property rights, considering that historical use generated vested rights.

Overall, these farmers consider that participating in the survey and expressing their opinion on scenarios would mean that they recognize the existence of the problem, which is not the case. Second, some of these respondents refused to participate in the survey as they considered the research team had no legitimacy to discuss these issues, since we were not mandated by an institution defending farmers' interests. There was a general fear that the conclusions of the survey be used against them, to justify decisions already taken, leading them to refuse to participate. These types of reactions raise the issue of procedural justice. Last but not least, some farmers refused to express an opinion on the scenarios presented because it involved too distant a timeframe (difficulty in adopting a prospective stance). Overall, opposition was expressed in a manner that was radical but well justified. Despite this refusal to discuss the scenarios, the farmers took time to consider and make explicit their vision, showing that they adhere to being stakeholders reflecting on water management, and wish to extend the field of possibilities.

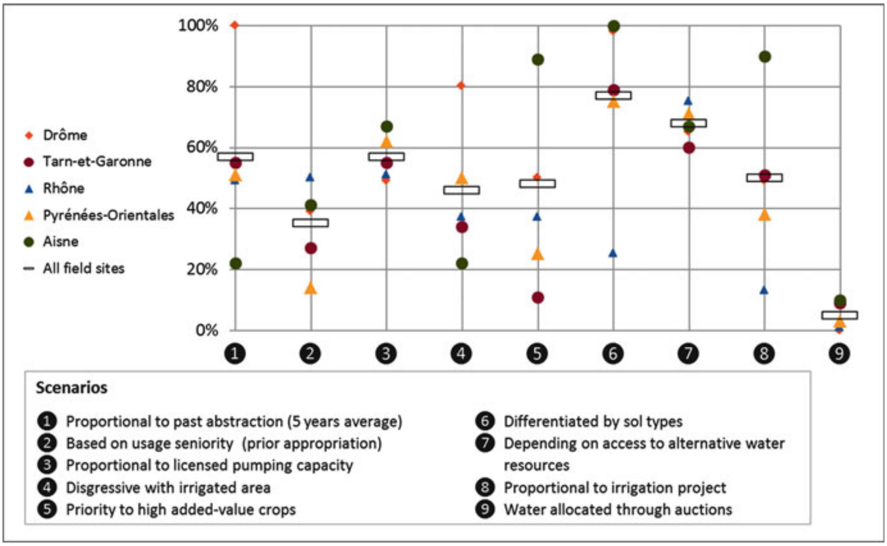


**Fig. 11.2** Answer to the question: "Does this scenario seem acceptable to you?" (The numbers correspond to scenarios described in Table **11.1**. Each colored sign corresponds to one of the five groundwater basins. The *horizontal rectangle* shows the average for the 47 farmers who accepted to assess the scenarios)

### 11.4.2 Overall Scenario Perception

A majority of the scenarios are the subject of highly contrasting opinions, and they are considered as acceptable by between 40 % and 60 % of the participants (Fig. 11.2). However, the two scenarios that compensate natural inequalities (allocation according to soil or access to surface water) received a higher approval rate of 77 % and 70 %, respectively. Conversely, the rationales inspired from Anglo-Saxon models received more modest support from the panel: 35 % (prior appropriation) and 4 % (sold at auction). Figure 11.2 allows the results to be compared according to the case studies. Opinions converge for the following scenarios: "sold at auction," "allocation according to seniority," "according to pumping capacity" and "according to access to surface water". For the other scenarios, opinions differ widely. These disparities show that, in order to be acceptable, a solution must be adapted to the local context. The new French water law (2006) position of delegating the calculation of quotas to Groundwater Water Users' Associations, operating at the aquifer level would, in our opinion, promote the acceptability of such a measure.

Through these results, we see that the preferred solution is often the one that disturbs the existing order as little as possible. The criteria that should be taken into account relate to the region's specific characteristics in order to correct natural inequalities amongst irrigators (soil diversity, access to surface water), while at the same time recognizing the farmers' needs (reflected by pumping capacity and past consumption). Criteria relative to economic efficiency (protection of special crops, markets) or protection for the most vulnerable users (digressive allocation) trigger more reticence and strongly polarize the stances taken by farmers. Excluding certain irrigators, whether on the strength of a financial criterion (sold at auction) or seniority, resulted in a systematic refusal on the part of the irrigators.

### 11.4.3 The Determinants of Acceptability: Justice Matters but Not Only!

The detailed analysis of tape recorded interviews highlighted that farmers form their judgment of acceptability by articulating four main categories of arguments: ethical considerations, including those related to justice; implementation feasibility of the scenario; risks associated with the scenario; and unintended side effects. These four categories were spontaneously advocated by farmers, although they were initially asked to comment on the justice dimension only.

Most of the arguments enunciated by farmers during the interviews reflect ethical considerations and are related to social and philosophical values on which the scenarios are based. For instance, the auction scenario provokes strong reticence on ethical grounds due to rejection of the monetization of water ("*water is not an economic good*"). The "digressive" scenario elicits reactions that are either favorable in reference to the solidarity principle or unfavorable when the scenario is equated with the logic of assistantship or charity. Certain farmers worry that scenarios might give rise to new inequalities (past consumption would penalize farmers who had already adopted water conservation practices), or would reinforce existing inequalities (according to the seniority of the irrigation, since younger farmers are still in the process of reimbursing loans). On the other hand, the soils scenario came across as liable to legitimately attenuate a natural inequality already suffered.

A second category of argument relates to the feasibility of implementation. A scenario may be accepted for its underlying ethical principle and yet be invalidated because its operational implementation is thought to be too costly or too complex. This can be illustrated by the scenario suggesting varying allocation according to soil differences; while this scenario was virtually always validated in principle, it was often met with skepticism as to its implementation (lengthy and conflict-ridden negotiations for classifying land parcels, in particular where the soil is highly heterogeneous within short distances).

Many farmers were also concerned by the prospect of risk allocation rules being misused. They refer to the possibility that unexpected opportunistic behaviors appear, that rules be abused during their implementation phase, diverting them from their initial objective. This dimension is brought up spontaneously, probably because of many experiences where similar agricultural policy tools missed their mark (e.g. allocation of milk production quotas). Thus, an allocation that varies digressively according to surface area, and supposed to encourage small farms, would spur large enterprises to break up into a host of small entities. Similarly, the decision to grant larger allocation to high added value crops could encourage farmers to increase the planted area of such crops just to obtain a greater allocation which they would in reality use largely for other crops.

The fourth category of arguments relates to the unintended consequences that allocation rules might have on farms, the structure of farming systems, or the regional economy as a whole. For example, many farmers think that the digressive scenario would result in decreasing the region's agricultural performance, as the most competitive farms would be handicapped by reduced allocation. Similarly, selling at auction would encourage hyper-specialization in certain crops, removing from business small diversified farmers who play a key role in maintaining an economic activity in rural areas. Giving priority to high added value crops (vegetable, fruits and certified seeds) would provide incentives for farmers to increase the area under such crops at the expense of traditional production, impacting the regional industry. By introducing a territorial dimension in their analysis, farmers show that the evaluation of water allocation policies should be embedded in a wider context, giving ample thought to the agricultural development model sought for the region.

This typology of arguments is useful to disentangle motivations underlying the level of acceptance of our nine scenarios, as depicted in Fig. 11.2. Overall, we see that the ethical dimension is essential, since the scenarios that give rise to a favorable ethical judgment receive strong support, and conversely. However, the diversity of moral principles does not, alone, account for the large variety of preferences. Implementation difficulties are widely cited as well as the risk of seeing new unjust inequalities arise through abuses, and unintended developments in the system.

### 11.4.4 Towards a Typology of Ethical Stance

In our interviews, the farmers did not cite a theory or ideal of justice to validate or invalidate the different scenarios. The first reaction was affective in nature, with a very vigorous rejection, for example, for sale at auction, which sparked shock or anger. Sometimes, it was even hard to get beyond this affective relationship, because it was too strong and hard to justify: "*I don't know how to explain it to you, but this scenario, I intuitively feel it will not work*" (farmer 41). We thus sought to understand how this sentiment of justice or injustice forms, that prompts farmers to validate or invalidate the proposed scenarios. We noticed that the statements were underlain by various rationales, some of which conformed with the current notion of social justice, and others not. We have accordingly established a typology of ethical stances, or rationales, into which we have placed the 47 irrigators. To assign the farmers unambiguously to one of the rationales, we based our judgment on their reasoning in regard to the scenarios, performing a qualitative (somehow subjective) classification of the salient aspects of what they had to say (based on the material collected through interviews, we were not able to clearly define the rationale of 5 of the 47 farmers). The farmers are distributed relatively uniformly,

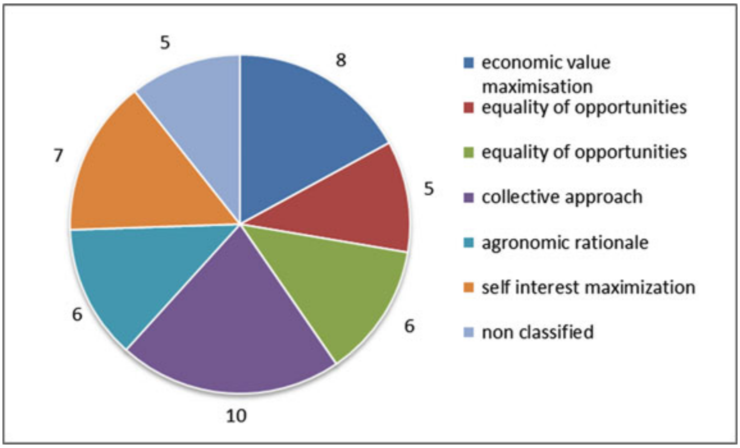


**Fig. 11.3** Classification of interviewed farmers according to the typology of rationale

with each category containing between five and ten individuals (Fig. 11.3). Each of the rationales is described below and illustrated, when possible, with selected farmers' discourse quotations.

**The Utilitarian Stance** "*In an emergency situation, irrigation of cereals should be reduced so as to irrigate crops produced under contract for the industry… The priority is to guarantee crops with a high added value" (farmer 38).* These farmers believe that water should be allocated in such a way as to maximize its economic value and protect the security of irrigators. The scarcer water is, the greater its value; it is therefore logical to allocate it to crops that generate the highest revenue. Note that this stance is not only defended by the most efficient producers. Some farmers are willing to sacrifice personal earnings to increase social welfare. Farmers of this group came out strongly in favor of scenario "priority to special crops" (❺). Yet they do set an ethical barrier to this principle, since very few of them accepted allocation via sale at auction (❾). Most farmers in this group rejected the "digressive allocation" scenario (❹), considering it as being "*too social*".

**The Egalitarian Stance** *"I don't like the idea of differentiating between Whites and Blacks, little and big guys" (farmer 28).* In a context of restriction, these farmers associate justice with equality of treatment. "*What is fairest, is to destabilize the economic system as little as possible with restrictions, it's better to apply the same restriction coefficient to everyone*" (farmer 28), with the twofold advantage of creating no new inequalities and being easy to implement. The allocation scenarios that propose a single coefficient of restriction (❶❾❹) were the ones that received strong support. Conversely, scenarios implying differential treatment are systematically rejected: sale at auction (❾), allocation according to seniority (❷) and digressive allocation (❹) all received 100 % negative opinions. However, a majority in this group validate the principle of differentiation according to soil (❻), probably motivated by an agronomical rationale rather than social justice consideration.

**Equality of Opportunities** *"I'm not a socialist, but I am sensitive to social issues. Everyone has to make an effort, but according to what he can. Nor should there be too great distortions, everyone has got to live" (farmer 17).* For these farmers, the level of effort (in terms of allocation cut-back) should be differentiated according to the characteristics and situations in terms of opportunities and difficulties of different farm types. This comes down to accepting positive discrimination as a moral principle of justice. The allocation policy for the water resource is thus similar to a mechanism of social redistribution (references to unemployment insurance, the pension system, the right to housing). Applying a uniform coefficient of restriction would confirm existing inequalities or even give rise to new ones. *"A young farmer setting-up a new farm without initial capital is disadvantaged as compared to one inheriting from a family farm, he should therefore not be subjected to further prejudice"* (farmer 11). This group widely approves the digressive allocation scenario (❹) and the allocation differentiated by soil types (❻). Protection of special crops (❺) is rejected, albeit differentiated. This system does not benefit the underprivileged.

**The Collective Approach Rationale** "It's hard to come to an agreement, but we've no choice. In the 1960s, they [the European Common Agricultural Policy] forced us to be individualistic, but there's no other way out for us but to reason collectively" (farmer 45). For this group of farmers, what matters is more the process leading to the choice of an allocation rule than the outcome in itself. In other words, this group is more concerned with procedural than distributive justice: if the decision making process is fair, final decisions on over-allocation will be accepted. They consider that the definition of a water allocation policy must not be reduced to the definition of individual water quotas, based on a negotiation where everyone defends their own individual or corporate interests. The design of water allocation rules should instead be taken as an opportunity for a societal debate on the type of agriculture to be promoted. Water allocation policy is a lever for a territorial and agricultural development policy. Farmers of this group consider that a user does not own water resources but merely is a custodian. These respondents defend the view, developed by Elinor Ostrom (1990), of a communitarian management of a common property, which can oppose management by the market or by the State effectively.

**The Agronomical Rationale** *"I don't like what you're suggesting: water management isn't a social affair, it's an agronomic affair" (farmer 20).* This group considers that irrigation is a farming practice, an act concurring with the production of crops like sowing, pruning or harvesting. It is determined by agronomic parameters (the plant's needs, the soil, the rainfall, etc.). Water allocation should be following the same rationale, i.e. be based on the same parameters; any other rationale constitutes an incursion of social and economic issues into a domain of technical agricultural efficiency. These farmers came out strongly in favor of allocation according to soil type (❻), according to past consumption (❶), and the pumping capacity (❸) which they consider good indicators of crop water requirements. The other scenarios, responding to a social or economic line of rationale, are deemed poorly adapted and far removed from the objective of promoting an efficient use of water. These farmers call into question how we have formulated the terms of the debate, by presupposing that water allocation involves issues of social justice.

**The Self-Interest Maximization Stance** *"Your questionnaire is doomed to failure, everyone will defend the scenario that suits him best" (farmer 10).* These farmers examine the proposed scenarios in the light of the situation on their own farm. The scenarios are evaluated one by one, according to the advantages and threats it presents for the respondent's own interests. *"I am one of the first farmers who developed irrigation in the region, I'm going to speak up for my own" (farmer 22).* This echoes some situations reported in Australian studies: "the forces of self-interest among water users become pre-eminent, and public involvement merely becomes a game of each stakeholder presenting his or her interest in the most favorable light possible" (Syme et al. 1999). No scenario emerges clearly from this group as the choice reflects individual heterogeneous situations. However, scenarios based on seniority, which is generally rejected by all farmers, is widely approved in this group (which confirms the rationale of preserving what has been gained).

### 11.4.5 The Individual Construction of a Hybrid Conception of Justice

Assigning each farmer to only one of the rationales described above is however too simplistic. Indeed if some respondents do clearly fall into one type or another, most borrow arguments, successively or simultaneously, pertaining to different stances. When they have come to perceive a modality of allocation as being too far removed from their position on one or another of these "poles", they came forward with an argument to strengthen this "frustrated pole". Thus, farmers positioning with respect to the different rationales is not binary (opposition/adhesion), but rather suggests a gradation in terms of acceptance. Farmers can mobilize two, three or even four principles. They do not oppose the principles with each other, but rather combine them to make up a corpus of values that they mobilize successively. It is accordingly by this composition, this ongoing compromise, that the sentiment of justice is formed.

## 11.5 Discussion and Conclusion

### 11.5.1 Summary and Scientific Contribution

This chapter proposes a method for evaluating the perception of justice and the acceptability of water allocation rules in over-used/over-allocated groundwater basins. We have endeavored to identify the factors determining acceptability for different principles of initial groundwater allocation. A first phase of this work was the design of contrasted scenarios depicting concrete rules for sharing the resource. These rules were inspired by an analysis of existing groundwater allocation practices in a selected number of countries and by a review of universal philosophies of justice. These scenarios were submitted to the scrutiny of 76 farmers from five French groundwater basins. The contribution of this study to the existing literature on justice and water allocation is threefold.

First, it complements existing Australian studies by providing empirical material relating justice issues to groundwater allocation problems in a European context. Moreover, the chapter focuses on the issue of water allocation within the farming community, whereas most of the existing literature deals with allocation between productive uses and the environment (a notable exception is (Nancarrow et al. 1998)). Our study confirms earlier findings that justice issues can be readily articulated by the farming community. We confirm that self-interest is only one of many different perspectives in the water allocation debate. We also invalidate our initial assumption on the existence of a limited number of dominant conceptions of social justice in the farming community, by showing that many different rationales coexist. The ways these principles are combined is likely to vary according to aquifer characteristics, land use and community culture (Syme and Nancarrow 2006).

Second, we highlight that acceptability of new water allocation rules is not only determined by how stakeholders perceive these rules in terms of distributive justice. Farmers' judgment is equally influenced by their perception of the legitimacy of the policy in which the question of allocation rule is embedded. Their arguments in that regard can be interpreted using the framework proposed by Suchman who distinguishes pragmatic, moral and cognitive legitimacy (Suchman 1995). Pragmatic legitimacy is determined by how farmers see their own activities and self-interest being impacted by the policy reform. Pragmatic legitimacy exists when farmers perceive that groundwater depletion will affect their self-interest in the long term, making abstraction regulation desirable. This was not the case in our French case studies where farmers only perceive the short term negative impacts on their income of the proposed regulation policy. Moral legitimacy refers to the normative judgment on whether the objectives of water policy promote social welfare, in line with moral values of a society. In that respect, French farmers challenge, on macro-economic grounds, the priority given to environmental issues over agricultural production. They also challenge the way the reform is implemented, with insufficient participation of stakeholders ("*we know how to manage groundwater, we won't be dictated a solution by a bureaucrat looking at this from his desk*": farmer 54) and the use of irrelevant policy models considered as universal by the administration ("*they [*government agencies] *want to use the same model from Belfort* [Swiss border of the Rhône river basin] *to the Italian border, in situations which have nothing in common*"; farmer 48). Finally, cognitive legitimacy is granted when the problem justifying a policy, the objectives and the means deployed to achieve them are understandable by concerned stakeholders. As explained in the result section, there was a clear lack of cognitive legitimacy in our French case studies, since many farmers were challenging the water scarcity assumption and refusing experts' evaluation of aquifer sustainable yield.

Our empirical results also show that acceptability of water allocation rules is also determined by their perceived implementation feasibility. Farmers make a very pragmatic evaluation of the difficulties that may arise with different allocation rules in terms of information acquisition and sharing, cost and complexity of operational functioning of the system, associated risks of conflicts, occurrence of deviant behaviors and unintended side-effect impacts. Overall, our empirical findings show that, when evaluating the different scenarios, farmers can alternatively use arguments related to social justice, legitimacy and implementation feasibility, in addition to self-interest considerations.

### 11.5.2 Implications and Policy Recommendations

Several policy recommendations can be derived from this empirical study, applying to the French context but also to other similar European contexts where groundwater abstraction regimes are currently being reformed.

First, there is a need to strengthen the cognitive and moral legitimacy of the groundwater abstraction policy reform before engaging stakeholders in a discussion of allocation rules. Stakeholders must first be convinced that a problem exists before discussing how to solve it. Government agencies and locally established GWUAs should ensure that stakeholders have a shared understanding of the groundwater situation, the extent of the overexploitation problem, of how sustainable yield was calculated and of the underlying trade-off made between environmental and economic objectives. Closing the gap between scientific experts' knowledge and farmers' lay knowledge is a prerequisite to engage farmers in a debate over how to share a limited resource among themselves.

Second, GWUA must also play a very proactive role in bringing out different viewpoints and perspectives held by farmers on distributive justice issues. Without a specific effort in that direction, there is a risk of seeing the debate play out not on the grounds of social justice, but rather on those of other dimensions of acceptability, and that the compromise on principles of justice give way to a balance of power. Such a shift occurred when fishing quotas were set in England (Gray et al. 2011).

The authors showed that what were deemed to be the fairest modes of calculation were not the ones that were actually chosen, but rather those that guaranteed the sector's stability and reflected the balance of power amongst the players.

The third implication is that the discussion over allocation rules should be embedded into a broader evaluation of alternative agricultural development policies at the groundwater basin level. Discussing intra-agriculture water allocation rules brings farmers to raise the question of what ideal the agricultural community should endeavor to achieve, for which the quotas policy would be one of the levers of action. Water allocation is clearly perceived by farmers as one of the many policy tools that can be used to shape future agricultural developments. It therefore can't be discussed in isolation, without considering the other levers over agricultural development.

Fourth, there is an overall social preference for allocation rule scenarios that compensate natural inequalities (allocation according to soil or access to surface water). Conversely, the rationales inspired from Anglo-Saxon models, including prior appropriation and auctioning are far less accepted. Lay philosophies of French farmers do not seem compatible with the current trend towards market driven approaches which are increasingly promoted at the European level (Commission 2012). From a methodological perspective, the study also demonstrates the relevance of using scenarios to help farmers in presenting and justifying their own vision, the principles they want to promote, the technical approaches they consider feasible or not, and to communicate this vision with each other. In addition to facilitating mutual understanding of existing visions, scenarios are likely to help farmers involved in the negotiation over allocation rules to identify a limited set of principles on which they want to base their allocation rule. Scenarios then provide building blocks that can be combined to construct a rule that can be considered as just by the largest number.

Last but not least, the analysis presented in this chapter has focused on the distributive justice issue only. Two other dimensions of justice should also be considered when crafting groundwater allocation rules: procedural justice, which reflects whether stakeholders have been given a fair access to the decision making process, and interactional justice, which is related to how people have been treated during this process (e.g. trust and respect). Acceptance of groundwater allocation policies will also depend on these two other dimensions (Gross 2011)

**Acknowledgements** The authors wish to thank the Rhône Mediterranean and Corsica Water Agency for the financial support provided for this research project (SIMGDES project). The paper has been prepared with the financial support of BRGM research program 30 (Environmental and Risk economics). We also thank Marian Patrick and Geoff Syme for comments on an earlier version of this chapter.

## References

Bennett M, Gardner A (2014) A regulatory framework for groundwater management in a drying South West: draft report for consultation. National Center for Groundwater Research and Training, Adelaide

Blomquist W, Schlager E, Heikkila T (2004) Common waters, diverging streams: linking institutions and water management in Arizona, California, and Colorado. Resources for the Future Press, Washington, DC

Commission E (2012) A blueprint to safeguard Europe's Water Resources. COM(2012) 673 final

DuMars C, Minier J (2004) The evolution of groundwater rights and groundwater management in New Mexico and the western United States. Hydrogeol J 12:40–51

Figureau A-G, Montginoul M, Rinaudo J-D (2015) Policy instruments for decentralized management of agricultural groundwater abstraction: a participatory approach. Ecol Econ 119:147–157

Garrido A, Llamas MR (2009) Water management in Spain: an example of changing paradigms. In: Dinar A, Albiac J (eds) Policy and strategic behavior in water resources management. Earthscan, London

Giordano M, Villholt KG (2007) The agricultural groundwater revolution: opportunities and threat to development. CAB International

Gray T, Korda RC, Stead S, Jones E (2011) Quota discarding and distributive justice: the case of the under-10 m fishing fleet in Sussex, England. Mar Policy 35:122–129

Gross C (2011) Why justice is important. In: Connell D, Grafton Q (eds) Basin futures: water reforms in the Murray Darling basin. The National Australian University Press, Canberra, pp 149–162

Hearne RR, Donoso G (2005) Water institutional reforms in Chile. Water Policy 7:53–69

Khalilian S, Froese R, Proelss A, Requate T (2010) Designed for failure: a critique of the Common Fisheries Policy of the European Union. Mar Policy 34:1178–1182

Lamont J, Favor C (2012) Distributive justice. In: Zalta EN (ed) The Standford Encyclopedia of Philosophy. Standford University, http://plato.stanford.edu/

Loubier S, Campardon M, Morardet S (2013) L'irrigation diminue-t-elle en France ? Premiers enseignements du recensement agricole de 2010. Sciences, Eaux et Territoires 11:12–19

Mill JS (1940) Utilitarianism, liberty and responsive government. J. M. Dent, London (Original work published in 1861)

Movik S (2014) A fair share? Perceptions of justice in South Africa's water allocation reform policy. Geoforum 54:187–195

Nancarrow BE, McCreddin JA, Syme GJ (1998) Developping fair processes for the reallocation of groundwater for long term sustainability in the Namoi Valley. Consultancy report 98*40. Australian Research Center for Water and Society, CSIRO Land and Water, Canberra

Nielsen K (1979) Radical egalitarian justice: justice as equality. Soc Theory Pract 5:209–226

Nozic R (1974) Anarchy, state and utopia. Blackwell, Oxford

NRMSC NRMSC (2002) Case examples of managing over-allocated groundwater systems. NRMM, Canberra

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge

Presser J (1994) Distributive justice in allocating individual catch quota in a fishery. In: 38th conference of the Australian agricultural Economics Society, Australian agricultural Economics Society, Wellington

Rawls J (1971) A theory of justice. Harward University Press, Cambridge, MA

Roa-García MC (2014) Equity, efficiency and sustainability in water allocation in the Andes: trade-offs in a full world. Water Altern 7(2):298–319

Ross A, de Santos M (2009) The challenge of groundwater governance: case studies from Spain and Australia. Reg Environ Change 10(4):299–310

Sadurski (1985) Giving desert its due: social justice and legal theory. In: Law and philosophy library, vol 2. D. Reidel, Dordrecht

Schlager E (2006) Challenges of governing groundwater in U.S. western states. Hydrogeol J 14:350–360

Suchman MC (1995) Managing legitimacy: strategic and institutional approaches. Accad Manage Rev 20:571–610

Syme GJ, Nancarrow BE (1996) Planning attitudes, lay philosophies and water allocation: a preliminary analysis and research agenda. Water Resour Res 32:1843–1850

Syme GJ, Nancarrow BE (1997) The determinants of perceptions of fairness in the allocation of water to multiple uses. Water Resour Res 33:2143–2152

Syme GJ, Nancarrow BE (2006) Achieving sustainability in water reform: a Western Australia case study. Water Int 31:23–30

Syme GJ, Nancarrow BE, McCreddin JA (1999) Defining the components of fairness in the allocation of water to environmental and human uses. J Environ Manage 57:51–70

van Koppen B, Schneiner B (2014) Priority general authorisations in right-based water authorization in South Africa. Water Policy 59–77

# Part III

# Biophysical Aspects