CHAPTER 13

Groundwater collective management systems: the United States experience

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ABSTRACT: Groundwater management in the USA is diverse and decentralized making generalizations sometimes difficult. In many areas groundwater is managed well under permit systems that prevent wasteful overuse and allow planned development. In other areas individuals are free to pump water with few restrictions and sometimes with wasteful consequences. This chapter provides an overview of collective groundwater management systems used in the USA by summarizing the types of systems in place and the advantages and disadvantages of each system. It concludes with an examination of what can be learned from the groundwater management experience in the USA and suggestions for the development of future groundwater management systems.

1 INTRODUCTION

The rules governing groundwater use in much of the USA and the world bring to mind the statement in Plato's Republic "I declare justice is nothing but the advantage of the stronger". Is this how things should be? In much of the USA and the rest of the world this is how it is. In this chapter we will examine the experience of the USA in the collective cooperation and management of groundwater resources.

1.1 *Groundwater use*

The USA is heavily dependent on groundwater, although this dependence (like almost everything about groundwater management in the USA) varies significantly from region to region. Nationally, according to the U.S. Geological Survey (USGS) groundwater provides an estimated 22% of all freshwater withdrawals, 37% of agricultural use (mostly irrigation), 37% of public water supply withdrawals, 51% of all drinking water for the entire population, and 99% of the drinking water for the rural population. These figures are somewhat misleading however. In many states more than half of the water used comes from the ground and in many others very little groundwater is used (Table 1 gives a state-by-state breakdown of groundwater use).

1.2 *Role of the national government*

To examine in a comprehensive manner the experience of managing groundwater in the USA is a daunting task. The first thing that one must understand is that there is no national *groundwater policy* nor, for that matter, is there any coherent national system of *groundwater management*. The system of groundwater management in the USA is highly diversified and decentralized, consisting of fifty state systems and sometimes many more (as within some states management systems have developed that make it difficult to generalize about how groundwater is managed even in a particular state).

To complicate matters even further, the different systems of groundwater management used in the USA are determined by political boundaries and almost never recognize geophysical boundaries. Consequently, an aquifer that straddles a political boundary may have one system of groundwater management governing the aquifer on one side of the boundary, and an

Table 1. Surface and groundwater use in the USA (adapted from: USGS 2000b).

State	Population (10^3)	Groundwater use (%)	Surface water use (%)
Alabama	4,250	6	94
Alaska	604	40	60
Arizona	4,220	42	58
Arkansas	2,480	62	38
California	32,100	32	68
Colorado	3,750	16	84
Connecticut	3,270	4	96
Delaware	717	7	93
D.C.	554	3	97
Florida	14,200	24	76
Georgia	7,200	20	80
Hawaii	1,190	27	73
Idaho	1,160	19	81
Illinois	11,800	5	95
Indiana	5,800	8	92
Iowa	2,840	17	83
Kansas	2,570	67	33
Kentucky	3,860	5	95
Louisiana	4,340	14	86
Maine	1,240	25	75
Maryland	5,040	3	97
Massachusetts	6,070	6	94
Michigan	9,550	7	93
Minnesota	4,610	21	79
Mississippi	2,700	81	19
Missouri	5,320	13	87
Montana	870	2	98
Nebraska	1,640	59	41
Nevada	1,530	40	60
New Hampshire	1,150	6	94
New Jersey	7,950	9	91
New Mexico	1,690	49	51
New York	18,100	6	94
North Carolina	7,200	6	94
North Dakota	641	11	89
Ohio	11,200	8	92
Oklahoma	3,280	60	40
Oregon	3,140	13	87
Pennsylvania	12,100	9	91
Rhode Island	990	7	93
South Carolina	3,670	5	95
South Dakota	729	41	59
Tennessee	5,260	5	95
Texas	18,700	30	70
Utah	1,950	18	82
Vermont	585	9	91
Virginia	6,620	4	96
Washington	5,430	20	80
West Virginia	1,830	3	97
Wisconsin	5,100	10	90
Wyoming	480	5	95
Puerto Rico	3,760	6	94
Virgin Islands	103	1	99
USA	**267,100**	**20**	**80**

entirely different system of management governing the aquifer on the other side of the boundary. For example, in New Mexico groundwater is managed by a state level official who issues permits to pump water based on the amount of water available in the aquifer and the expected life of the aquifer. Yet in bordering Texas there is no such state authority, and much pumping occurs in Texas that is governed by nothing other than the willingness of a landowner to drill a well and pump. The result is, on this border and others in the USA, a situation where water is managed well on one side of the political boundary and not managed, in any real sense, on the other (often to the determent of the side that manages its water well).

1.3 *Summary of contents*

In this chapter, we will first review a brief history of groundwater management and development in the USA, paying particular attention to the role of government over time; and then summarize some of the pressing groundwater management problems that face the USA, and examine the barriers that these problems can present to effective, cooperative groundwater management. Then we will summarize the political and legal systems that govern groundwater management and allow for rational, collective groundwater management decisions. (Or, as is often the case, makes such decisions difficult). Finally we will examine what the USA experience might hold for other countries trying to manage groundwater effectively.

2 HISTORICAL OVERVIEW

In the USA water management in general, and groundwater management in particular, has been the responsibility of local governments. In the late 1800s the USA Congress passed several bills that prohibited discharging of refuse and anything else that would impede navigation into the nation's rivers. These were measures designed primarily to facilitate trade among the states consistent with the federal government's responsibility to oversee interstate commerce. In the early and middle 1900s, the federal government was involved in surface water development projects primarily through the dam building and other construction activities of the U.S.

Army Corps of Engineers and the U.S. Bureau of Reclamation. Then in the early 1970s, the federal government again became involved in water management with the passage of pollution control laws which basically set up requirements for water pollution control that are administered by state governments.

Although some of this federal activity impacted groundwater management, the federal government nearly always acted pursuant to state and local law and did not exercise any independent federal authority over groundwater management.

2.1 *The federal government*

Given the extension of the federal government into a wide variety of domestic issues, there's no reason to conclude that the federal government could not have become involved in groundwater management if it had chosen to do so. The federal government has used the federal commerce power of the USA Constitution as the grounds to insert itself into many activities that might otherwise have been considered the responsibility of state and local governments. In groundwater law specifically the USA Supreme Court addressed this issue in the late 1970s and early 1980s wherein the court found a constitutional basis for the management of groundwater (Smith 1986). Finally the federal government has clear authority over the management of groundwater resources on *federal reservations*. Federal reservations include any lands that have been reserved for some federal purpose and, perhaps most importantly, Indian reservations. On a federal reservation the federal government (or tribal government in the case of Indian reservations), has reserved to it the right to use water that originates on the reservation in any way that is consistent with the reason for originally creating the reservation. These water rights date to the time of the creation of the federal reservation and are superior to rights that may be created by state governments subsequent to the creation of the reservation. Yet even in a federal reservation situation, where the federal right to manage groundwater originating on federal lands is clearly superior to any state law, the federal government has, in many instances, deferred to state law and opted to follow state permitting procedures. This exemplifies the extent to which the federal government has been willing to concede the regulation of groundwater to state and local governments. (It should be noted that tribal governments on federal Indian reservations have not been as willing to differ to state authority.)

In summary, the role of the federal government in groundwater management in the USA has been limited. However this limitation is not due to any constitutional or legal barriers, but rather is self imposed and due to historical and cultural factors. Such limitations are not uncommon in many large (federal) countries including India, Pakistan, Brazil, and the People's Republic of China.

If the role, or lack thereof, of the federal government is the first thing that one must understand when examining groundwater management in the USA, then surely the second most important fact is the topography of the land and the relationship between land formation, historical patterns of settlement, and groundwater law. Groundwater management systems in the USA have formed in large part in relationship to the form and volume of groundwater found in a particular region and the period in which the region was settled.

2.2 *Topography and settlement*

The USA is a physically diverse land area. Within the boarders of the USA, you can find climates that range from the tropical to the arctic, as well as rainfall averages of less than 51 mm/yr to over 10,160 mm/yr of rain (USGS 2000b). These extremes have resulted in numerous different adaptations and innovations in water management. Knowledge of the diversity and climate conditions is vitally important to understanding the management of water issues, particularly groundwater.

Geographically the USA is bordered by the Pacific Ocean on its western coast and the Atlantic Ocean on the east. The Southern border of the USA buttresses Mexico from Texas to California and the Gulf of Mexico from Texas to Florida. The northern border of the USA is shared with Canada. Moving from east to west from the Atlantic seaboard to the base of the Appalachian Mountains, much of the east coast consists of low-lying rolling hills. On the west side of the Appalachian Mountains begin the central plains that are home to much of the nation's agriculture. The central plains lead up to the Rocky Mountains, and the further one

moves towards the west the more arid the climate. The Rocky Mountains are the highest landmass in the continental USA, reaching 4,267 m. West of the Rockies, from the border of the central plains to the Pacific Coast, is very arid and includes the region stretching from Eastern Washington in the north down to the southwestern states of Arizona and New Mexico. On the far west of the USA the west coast varies from quite arid in Southern California to very moist in the Pacific Northwest.

When studying water in the USA, a repeated point of demarcation is that of the one-hundredth meridian. This defining line runs north and south through Texas, Oklahoma, Kansas, South Dakota, and North Dakota and is generally the mark between those areas that get 508 mm/yr of moisture or more and those that get less. Most of the early settlement in the USA was well east of the hundredth meridian in those parts of the country where rainfall was predictable and sources of water, both above and below ground, plentiful. Consequently, groundwater law and management systems originally developed in parts of the country where water scarcity was not an issue.

2.3 *Development of law*

Most of the original white settlers of what was to become the USA emigrated from England. These settlers brought with them the legal systems with which they were familiar. In groundwater management this means they brought a property rights system that has come to be known as the absolute ownership doctrine or *English Rule*. Under the absolute ownership doctrine, or the *English Rule*, the owner of the surface is the owner of all that's underneath the soil whether it is solid, semisolid or fluid. The *English Rule* or the absolute ownership doctrine was the basis for groundwater law throughout most of the history of the USA and still forms the basis of that law in most states, particularly east of the one-hundredth meridian. The first modification of the *English Rule* was something called the *American Rule* or the rule of reasonable use. Simply stated the *American Rule* of reasonable use held that every owner of surface land had a right to withdraw groundwater and make use of that water, if such use is reasonable, and if the water is used beneficially on the land from which it is taken. Under the rule such use may be reasonable even if the water is used on other land provided that it does not injure neighboring landowners. Finally, if the water is used on land other than that from which it is withdrawn it is unreasonable and illegal if it interferes with or injures the use of neighboring property owners. This relatively simple modification of the *English Rule* is quite important, and still underlies most groundwater law in the USA. Prior to the adoption of the *American Rule* of reasonable use a land owner could pump as much water as he or she wanted to without concern about the impact that such pumping might have on neighboring land owners. All of these laws will be discussed in greater detail below.

Although most states follow some adaptation of the *American Rule* of reasonable use, there have been several variations (notably in the western more arid part of the USA). The most important of these developments was the prior appropriation doctrine. The prior appropriation doctrine has had its greatest impact felt on the law of surface waters in the Western USA, but a number of states have used variations of prior appropriations to govern groundwater use as well. Basically, the prior appropriations doctrine holds that those extracting water from the ground can fix their right in time based on when they started the appropriation. In other words, first in time first in right. In surface water law this means that the right to extract water from a river may or may not be connected to the ownership of land adjacent to that river (this is exactly the opposite of the riparian doctrine for surface waters that is followed in most of the Eastern USA). In groundwater, prior appropriation has developed differently. Prior appropriation in groundwater almost always requires some form of land ownership (the exceptions being when the right to extract has been sold or transferred). Hence, the right to appropriate is still based on land ownership, although the volume or amount that may be withdrawn, in some states, is determined by the priority of the appropriation. So for example if three adjacent landowners are all pumping an equal amount of water and there is a shortage of groundwater, to determine who might be required to curtail their pumping the courts or a government administrator would, among other things, seek to determine when each individual started their pumping and how much they had been pumping.

Most developments in groundwater law occurred in the Western USA –both in western courts and legislatures. Technological changes occurred in the ability to pump water from the ground, which lead to the rapid expansion of groundwater pumping, and the development of irrigated agriculture. These things made clear the limitations of the legal doctrines governing groundwater use and ownership. As it became possible to withdraw greater amounts of water from greater depths, competition for water developed in some areas. Legislatures in the West reacted to conflict over groundwater resources in a variety of ways. They changed their laws (or perhaps not), depending upon the controversies involved, the participants, the interests, and the pressure lawmakers felt. Some states, due to early conflicts over groundwater (New Mexico, for example), were quick to write relatively comprehensive groundwater management statutes. In other states, notably Texas and California, early water law has changed greatly yet retained significant parts of the old law, as it existed prior to the rapid development of groundwater resources. The four major groundwater law doctrines followed in the USA are outlined in greater detail below, along with a general discussion of how groundwater law has changed since the turn of the century. Interestingly, although there are some important exceptions –particularly dealing with Crown (national government) Lands– these four doctrines are also followed in Canada.

The four primary legal doctrines governing groundwater use then are the English, or common law, rule of absolute ownership, the *American rule* of reasonable use, the correlative rights doctrine, and the doctrine of prior appropriation. Generally, groundwater law in the western states has evolved during this century from the English, or common law, rule of absolute ownership to either the *American rule* of reasonable use or (in most western states) the doctrine of prior appropriation.

As we have seen the common law, or absolute ownership doctrine, holds that the water beneath one's land is the property of the landowner and may be withdrawn, without malice, with no regard to the effect that withdrawals have on any other landowner. In theory, and in practice in many areas, this meant that landowners could pump at will the water beneath their lands as well as the water beneath the lands of their neighbors. The absolute ownership doctrine was developed in England and transferred to the relatively wet East (where it is largely still the law). The doctrine works reasonably well in areas where there is abundant water available. Familiar with water law in other parts of the country, many courts and legislatures in the western states, early in their history, adopted the common law rule. With minor amounts of groundwater withdrawn in early western history and the lack of competition for groundwater resources, the absolute ownership doctrine seemed the reasonable course to pursue. However, when competition for water did develop in the West, it became apparent that there were drawbacks to the absolute ownership doctrine in an arid environment. It was shortly after competition for water developed that modifications of the rule started to be made.

One modification made by many courts in the West was the reasonable use doctrine, or the *American rule*. Basically, the reasonable use doctrine limits a landowner's right to the water beneath his or her land to that amount necessary for some reasonable and beneficial purpose on the land above the water. The waste of water or the transportation of water off of the land was not considered a reasonable beneficial use if such use interfered with the right of adjacent landowners to use the water beneath their own lands for the beneficial use of those lands.

Some states, notably California, developed the correlative rights doctrine as an alternative to the absolute ownership doctrine. Basically, the correlative rights doctrine recognizes the landowner's right to use the water beneath his or her lands but limits that right somewhat by providing that landowners overlying a common source of groundwater have equal, or correlative, rights to a reasonable amount of that water when the water is applied to a reasonable beneficial use on the land overlying the groundwater basin.

Most western states have adopted some form of the prior appropriation doctrine. The prior appropriation doctrine simply provides that the first appropriator of water, by putting that water to beneficial use without waste, has a right to continue that use. And such rights are superior to the rights of people who appropriate water at a later date. In prior appropriation states, water rights are usually administered by a state official or office (often a state engineer) through a permit procedure.

The overwhelming majority of western states found that the common law was ill fitted to the arid West and changed to one of the other doctrines, usually the prior appropriation doctrine (Ashley & Smith 1999).

2.4 *Beneficial use*

The concept of *beneficial use* repeatedly comes up when examining groundwater policy and law as a beneficial use is almost always a requirement of groundwater use. The Utah Code is typical when it states in section 77-1-3 that beneficial use "shall be the basis, the measure and the limit of all rights to use water in this state". The beneficial use concept was developed during the 19th century to encourage economic efficiency. Although it may seem straightforward what is *beneficial* has meant different things to different people. Some uses have always been considered beneficial (for example, water for domestic purposes or for irrigation, manufacturing, or stock watering), it is beyond these traditional uses where there sometimes is conflict and controversy over what constitutes a beneficial use. For example, some courts have found water needed for the protection and propagation of fish to be a beneficial use, while others have not. Courts and state legislatures have also been split on the issue of whether or not water necessary for recreation, fish, aesthetic, or scenic uses is a beneficial use of water. (This can be a problem in groundwater regulation because of the relationship between surface water and groundwater in streambeds). For example, in Arizona water can not be reserved to protect the life of a stream (the flora and fauna in the streambed), as that is not considered a beneficial use in that state. In contrast beneficial use in the State of Washington Code section 90-54-020 also includes water for aesthetic and fish or wildlife purposes. In New Mexico the State Engineer once determined that mine dewatering (the pumping of water out of the ground –which then becomes waste– so that the ground can be mined), was not a beneficial use and that hence he had no legal basis to control mine dewatering.

2.5 *Social functions of groundwater*

It is difficult to understand the importance of groundwater law without taking into consideration the social functions that water law has served and how changes in the law have mirrored changes in water use and society. Stability of water ownership is essential for economic growth and long-term planning. Farmers or cities are not likely to build expensive water development facilities if their ability to use to the resource may be called into question at some point in the future. It may have appeared to policymakers early in the history of the country that the common law doctrine, or the absolute ownership rule, would provide the stability necessary for long-term planning. In fact, in the absence of competition for water resources, the common law doctrine did provide that stability. However, when competition began to create conflict for groundwater resources, it became clear that one pumper might find the use and enjoyment of his or her groundwater threatened by the activities of pumping on adjacent lands. Converting to the doctrine of prior appropriation, as most western states did, provided the stability necessary for pumpers to understand what their rights were and to plan for the long-term use and development of their water.

This same stability, however, has tended to favor those interests that were early to acquire their water rights, and, to the extent that water laws prevent the transfer and change of ownership of water rights (as they do in some states), the law has favored those historical uses and has prevented change in water use patterns and the development of alternative uses. So groundwater law has provided stability necessary for economic growth and expansion. In later years, that same stability has, in some states, prevented changes in water use and, some would argue further economic growth and development. Some states, as we will see, have responded very little to changing groundwater use and conditions. The result, in some cases, is that the resource is poorly managed if managed at all.

3 GROUNDWATER PROBLEMS

To better understand the challenges facing groundwater managers in the USA –or stated another way, the obstacles to cooperative management, we need to understand the groundwater management problems facing those managers. Like groundwater management laws, groundwater problems vary from region to region yet there are a number of recurring issues when one exam-

ines groundwater policy. Overdrafting (the extraction of water from an aquifer at rates that exceed natural recharge), land subsidence, pollution, saltwater intrusion, and the division of responsibility over who should manage groundwater resources are issues that often arise in the USA as elsewhere. The diversity in the states and differences in their hydrologic, political, and legal environments make generalizations difficult, but clearly the different legal and management systems employed in the USA have impacted the ability of the states to deal with these problems.

3.1 *Scarcity*

In the arid Western USA the primary problem is one of overdrafting –or scarcity. Probably the best-known overdrafting situation in the West has occurred in the Ogallala aquifer, a huge water source for the Great Plains area that includes portions of New Mexico, Texas, Oklahoma, Kansas, Colorado, Nebraska, Wyoming, and South Dakota. Covering an area of roughly 647,000 km^2, the Ogallala supports one-fifth of the irrigated agriculture in the USA. In some places pumping from the Ogallala has resulted in the withdrawing of water at a rate 14 times faster than its rate of natural replenishment (Russell 1985). Again, the impact of overdrafting on the Ogallala varies significantly depending upon the region. For example, in the Texas panhandle many farmers have already converted to dry land farming (i.e. without irrigation), whereas Nebraska is comparatively untroubled.

In a situation of scarcity there is naturally competition between groundwater users and pressures put on management systems to manage waters in an equitable manner. In states that still follow the absolute ownership doctrine, like Texas, competition ultimately has led to the depletion of the resource –overdrafting to the point of the water becoming useless for most economic purposes. In states with well-defined management systems (discussed below), overdrafting has led to redistribution and regulation of water resources. When groundwater depletion and overdrafting is planned for, competition, over utilization, and economic disruption can be minimized. In some regions overdrafting (or more correctly mining in this context) may be the only rational way to manage the resource (e.g. in areas where aquifers are, for all practical purposes, not being naturally replenished). Unfortunately aquifers are sometimes managed (or perhaps more accurately, not managed) with little thought of the future consequences and foregone opportunities.

3.2 *Land subsidence*

A problem related to overdrafting is land subsidence. Prior to the lowering of the water table in a given groundwater basin, the soil is partially supported by grain-to-grain contact and partially supported by the surrounding water. The removal of the water in such a situation causes vertical and horizontal stresses and may result in the settling or subsidence of the land surface. Land subsidence has been a problem impacting more than 44,030 km^2 of land (an area roughly the size of New Hampshire and Vermont combined) in 45 States (USGS 2000a). Like overdrafting land subsidence has often not been addressed in states that still follow the absolute ownership doctrine.

3.3 *Pollution*

Another groundwater management problem is pollution –either in the form of pollution from substances on the surface getting into groundwater basins or pollution from salt-water intrusion. Water may be polluted by salts either occurring naturally or by virtue of the migration of saltwater into fresh water resources. Pollution, whether or not it occurs in the east or the west, usually involves an entire different set of players. In the USA, pollution activities are generally governed by one set of laws whereas other laws govern allocation and use activities. Consequently groundwater pollution, with the exception of salt-water intrusion, will not be discussed here. Salt-water intrusion also has a mixed management record. Although states that still follow the absolute ownership doctrine have not managed this problem well neither have many other states following various other management systems.

4 GROUNDWATER MANAGEMENT REGIMES

By now it should be clear that the management of groundwater resources in the USA is a complex system that varies significantly from

region to region. It might be useful to describe types of groundwater management systems as existing on a continuum that varies depending upon the amount of government control, as it can be seen in this relation:

1) No regulations.
2) *English Rule*: absolute ownership.
3) *American Rule*: reasonable use and correlative rights doctrine.
4) Government controls of type and rate of extraction under special circumstances (usually under prior appropriation).
5) Government controls of type and rate of extraction under all circumstances.

On this continuum on the first step (1) we would find anarchy or no government control or regulation whatsoever. Although there is no anarchy in groundwater management in the USA (property ownership is a minimal requirement even in the most lax systems), the absolute ownership doctrine comes fairly close. On this side of the continuum the owner of land may do as s/he pleases with that water beneath the land. Parts of Texas and California in the Western USA and several eastern states fall into this category. On the last step (5) of the continuum we would find total government control over the administration withdraw and use of groundwater. Although there are no systems in the USA that involve this level of control there are some systems, notably those in which groundwater withdrawals are regulated by a state level bureaucrat through a permit system, which come close (Oregon, Washington and New Mexico are examples). The states and regions of the USA fall somewhere between number two and four on the above continuum. The regimes which fall closer to number four and five on the continuum are those that are most likely to have the tools necessary to actively manage groundwater (by doing things such as setting up recharge systems, importing and injecting water or regulating pumping).

To attempt a state-by-state breakdown of the legal regimes that govern groundwater in each of the 50 states and their many political subdivisions in the USA is beyond the scope and capacity of this chapter. Although the reader can find such breakdowns elsewhere (Ashley & Smith 1999). Instead a sample of types of systems representing the various types of management in the above continuum will be presented. Through each of these descriptions the reader will be exposed to the wide variety of collective management systems in use in the USA. Again generalizations are difficult but I have categorized the examples into: collective district management systems, court appointed watermasters, weak district management, little or no management, and state permit systems.

4.1 *Water districts*

In many parts of the USA, primarily in major metropolitan areas and where severe overdrafting has caused economic disruption, water districts have been created, either by the courts or state legislatures, and given authority over groundwater management in their jurisdictions. Water districts take on a variety of forms. Some are created by a specific legislative act; others are created under general acts that allow for district creation under local option. Methods of selection of district governing bodies vary from independent election by all district voters, election by property owners and various methods of appointment. There are thousands of such districts in the USA. These districts vary significantly in their powers, functions and methods of creation but often they have the authority to levy taxes, issue pumping permits, issue both general obligation and revenue bonds (borrow money), and set rates for service.

The Orange County Water District (OCWD) in California, which has been referred to as a leader in the water district non-adjudication approach to groundwater management, provides an example of groundwater management by local district. The OCWD has extensive powers to require data from groundwater pumpers; regulate pumping patterns; levy a pump tax and through a *basin equity assessment* regulate the cost of groundwater in order to influence the amounts of ground versus surface water being used. A major function of the OCWD is to recharge groundwater basins with imported surface water and natural run-off. For this purpose the district owns 405 ha in and adjacent to the Santa Ana River. The OCWD also has a comprehensive salt-water intrusion mitigation plan consisting of a series of barrier pumps along the California coast designed to prevent intrusion (Smith 1984).

4.2 *Court watermasters*

In states where the courts have adjudicated groundwater rights, the courts have sometimes appointed a water master to manage groundwater basins consistent with court rulings. The powers of a watermaster are similar to those held by water districts. For example, the San Gabriel California watermaster, a nine-member court-appointed body, can operate a groundwater replenishment program, control basin storage and levy a *replacement water assessment* on the amount of withdrawal in excess of a pumper's adjudicated share. Watermaster arrangements are particularly prevalent in California, where nearly all groundwater basin wide court cases have ended with parties reaching agreement on the allocations they believe to be fair and reasonable, and agreeing to watermaster management.

4.3 *Collective management*

These two examples of district collective management systems are management arrangements that fall somewhere between three and four on the continuum presented above. They can have fairly strong authority to manage groundwater in a way that will prevent waste and will lead to the orderly development of groundwater resources. However not all districts are created alike. Districts can just as easily be created with limited powers, and very little ability to control groundwater pumping or provide any kind of real management. Such types of districts are not uncommon in the USA. For example, since 1949 Texas has allowed the voluntary creation of underground water conservation districts (UWCDs), with discretionary power to regulate groundwater withdrawals as long as landowners did not lose their *ownership* of groundwater. UWCDs have the power to provide for the spacing of wells and to regulate the production of wells, and other powers to enable them to, as the Water Code (section 52.117) states "minimize as far as practical the drawdown of the water table". Although over forty UWCDs have been created in Texas, they have not, for the most part, been effective managers of groundwater (only one –the Harris-Galveston Coastal Subsidence District– has directly regulated pumping). Well spacing requirements undertaken by some districts have slowed groundwater development and depletion in some areas but no attempts (except Harris-Galveston –the Houston area– where subsidence has been a major and serious problem) have been made to control groundwater pumping and thereby extend the life of the aquifer. This failure (which it may or may not be, depending on one's perspective –clearly many groundwater pumpers are happy with the *status quo*) is due to the fact a landowner's absolute right to the water beneath his or her land cannot be abrogated by a UWCD, and counties (local units of government) can decide not to be part of a UWCD when it is created. As this example shows creating groundwater management districts is not –in and of itself– going to insure sound groundwater management. The composition and powers of a district are as important as the creation of a district itself.

4.4 *Limited controls*

Texas also provides a good example of the next type of *management* examined here –no or little management. In many parts of the USA groundwater pumping is virtually unregulated (a permit may be required but this is a formality in some places). Although often this occurs in rural unpopulated areas (and therefore is not a problem), it also sometimes occurs in populated areas and sometimes occurs with the result that competition or the resource leads to economic disruptions. In rural areas all over the USA wells can dry up when neighboring landowners dig deeper wells and lower water tables. In parts of Texas and Oklahoma, as well as elsewhere, lowered water tables have forced farmers out of irrigated agriculture. This is a type of water management we see in areas all over the world. Sometimes referred to as the right of capture and not always connected with land ownership, groundwater managed in this manner is only *managed* in the loosest sense of the term. The disruptions of non-management of groundwater basins are familiar to the readers of this volume. This is a particularly difficult problem in groundwater basins that cross-political borders. In those situations, competition for water can lead to depletion of the resource and economic and social disruption for people on both sides of the border. (This will be discussed in greater detail below).

4.5 *Permit systems*

The next type of groundwater management system we will examine is best described as statewide permit management systems. Typically this type of management involves a single government authority (often called a state engineer in the USA –someone who is usually appointed by the state chief executive) that has the responsibility to issue drilling, well spacing and extraction permits for groundwater. However, these water managers vary significantly both in terms of their formal powers and how they choose to administer the powers that they have. In some states, such as Arizona and New Mexico, state jurisdiction only applies to those areas where the state has asserted jurisdiction (in Arizona, for example, through the creation of a Groundwater Active Management Area by the state legislature or other means and in New Mexico through the designation of a groundwater as a *declared groundwater basin* by the state engineer). In other states authority extends statewide. In nearly all cases this office determines how much water is available where and makes decisions determining its allocation where there is surplus water or where a water right becomes available. That is about where the similarity ends. In some states, notably in more humid climates and where aquifers recharge naturally, groundwater may be managed on a safe yield basis, permits are issued for the extraction of amounts of water roughly equal to the amount of water that returns to the aquifer each year. It is interesting to note, however, that law rarely mandates this groundwater management philosophy. Most of the laws governing how state officials should issue permits are written in a similar way –but are interpreted differently. For example, the North Dakota State Water Commission and the North Dakota State Engineer have been managing the state's groundwater resources via a permit system in a manner designed to prevent groundwater overdrafting for many years. Although there is no provision in the North Dakota Code that requires the state engineer to do so, the engineer has interpreted Section 61-04-06 (which is similar to laws in many states and directs that permits for water only be issued when there is unappropriated water available), as providing the authority to manage groundwater on a long-term safe-yield basis. Consequently, with one minor exception, there is very little overdrafting in the state. In contrast in Oklahoma, New Mexico, and other states, the amount of water available in a groundwater basin is determined and permits are issued with the specific knowledge that the water being withdrawn represents overdrafting and that the aquifer will eventually be depleted (the years allowed until depletion vary from 20 to 100). In these primarily arid states management is predicated on the idea that the water being managed is essentiality non-rechargeable, so the decision has been made for the orderly depletion of the resource.

It is difficult to generalize about where on the above continuum state permit systems fall. As some follow the *American Rule*, others follow forms of prior appropriation and all vary in terms of the practical application of whatever form of management followed.

5 COMPETITION

The primary focus of this book and this chapter is groundwater competition and how it is or should be managed. It is this author's opinion that the value of the groundwater management experience in the USA for the rest of the world is primarily in how to avoid certain problems. The USA may have a lot to teach the world about what not to do in this instance. Before pursuing that argument we will first examine groundwater competition in the USA and how the systems in place for managing groundwater have dealt with competition.

First it should be noted that competition for groundwater resources within the states of the USA has often been managed reasonably well. Most states have, either through the administration of permit systems, the creation of management districts, or through court decisions, found ways to minimize competition for groundwater resources. In several notable examples, however, largely in the southwest and lower mid-west, competition has not been managed well with the result that some water users have been forced out of business. Also in some cases, notably in California, the transaction costs of stable management (the time and resources that have been expended to achieve sound management), have been great and hence these situations cannot be recommended.

At the risk of being redundant, by way of introduction, let me cover some familiar ground.

Since groundwater is a common pool resource, international and interstate competition for groundwater resources can result in inefficient management of those resources. In common pool situations, the problem is primarily one of a lack of definition and enforcement of water rights. By not utilizing the water available beneath the soil, a groundwater pumper may be saving that water for use at some future date, but may also be running the risk that some other extractor will take the water first.

There is competition for groundwater along many parts of the USA-Mexico border. With the exception of the Yuma area, there is no international authority that can prevent either country from increasing groundwater extractions. Competition for groundwater resources along the USA-Mexico border will likely intensify in coming years, in part because of projected population increases and increased industry on both sides of the border. This situation encourages each nation to surpass its neighbor by developing its groundwater resources as rapidly as possible. If allowed to continue, it could lead to the point of depletion for practical purposes the groundwater resource. The situation is similar on interstate borders in the USA and along parts of the USA border with Canada.

5.1 *In the USA*

In an effort to measure the extent of competition for groundwater resources on interstate and international borders in the USA, I conducted a survey of water managers and other experts in the 48 contiguous states. In this survey, 302 water policy makers and administrators, university faculty and others concerned with water management in the 48 contiguous states, and Mexico and Canada, were identified through an *Internet* search conducted on each state and province. These individuals, in September 2000, were mailed a questionnaire requesting the location of any interstate/international aquifer where there was competition for groundwater. Respondents were also asked the name of the aquifer and to identify any problems related to competition. Survey participants were also mailed self-addressed envelopes and individualized cover letters explaining the study. 92 responses were received. There was no discernible trend to the nonrespondents. Follow-up letters and a second questionnaire were sent to states where no one responded. In states with heavy interstate competition and/or problems response rates were close to 100%.

The study found that there was significant competition for groundwater resources all over the contiguous 48 states and in several areas along USA borders. Also many areas were identified where competition may be expected to develop in the future. For a detailed summary and a map available on line the reader is referred elsewhere[1]. The survey results show, in part, how the groundwater management systems that have developed in the USA have adapted to conditions of competition. Although there are instances of informal agreements where, outside the force of law, groundwater pumpers have made sharing arrangements, there are many more cases where competition continues and promises to lead to poor management of the resource. In many cases one state is powerless to curtail the pumping taking place in an adjacent state. In some cases this pumping is specifically designed to remove water form an adjacent state that is powerless to control the withdrawals.

The national government could intervene to manage groundwater but the political costs of national intervention are great and the states are usually more or less even players on the national level. Furthermore the national government has traditionally shown no interest in intervening in state groundwater management. All of this means that the states are more than likely going to have to deal with interstate competition on their own –there is no national groundwater policy that will deal with this problem and the laws of the several states are not well suited to dealing with this problem.

6 WHAT DOES IT ALL MEAN?

As is abundantly clear to anyone who studies groundwater management on the planet, we need to develop systems for managing groundwater under conditions of scarcity, which will allow for planned development and social equity. Should water use and management be deter-

[1] The full results are scheduled to be published in an upcoming edition of *Water International* the quarterly journal of the International Water Resources Association. A map showing the areas of identified interstate competition can be found at http://jan.ucc.nau.edu/~zas/ISGWMAP.htm

mined by who has the most money to dig deeper and sink more powerful wells? Is there a societal interest that should influence who gets how much water? If the answer to the first question is no, then the answer to the second question is yes. What can we learn from the groundwater management experience in the USA?

6.1 *Lessons from the USA*

In the USA, as in other countries, the formation of law and policy is greatly influenced by what many scholars refer to as our dominant social paradigm (DSP) (Smith 2000). The DSP constitutes those clusters of beliefs, values, and ideals that influence our thinking about society, the role of government, and individual responsibility. The DSP in the USA can be defined in various ways but includes acceptance of *laissez-faire* capitalism, individualism, limited government, growth as progress, and a faith in science and technology. Perhaps the most important components of the DSP in the USA are free market economics, faith in science and technology, and a growth orientation. In groundwater policy in the USA the DSP creates an environment in which it is very difficult to limit individual pumping (which represents the freedom to do as one pleases with ones property) or create governmental institutions with the powers necessary to manage groundwater effectively (due to an overall suspect of government and desire for limited government). Consequently, in many cases sound groundwater management in the USA has often only occurred when problems reach crisis proportions (like the land subsidence in Texas, or the salt-water intrusion in many parts of the country).

In this era of globalization, when much of the world is rushing to embrace free trade and market economies, the dominant features of the DSP in the USA are being exported and adopted in many places that previously had other types of political and social traditions. The USA has never had a communitarian orientation toward its citizens and terms like *social democracy* or *social capitalism* are likely to elicit critical responses when introduced into political dialog in the USA.

Hence, both because of its inability to manage water effectively, efficiently and equitably in some areas, and because of underlying political principles which may not be consistent with the political, cultural and social conditions in other countries, the USA groundwater management regime may be one not worth importing.

The groundwater experience in the USA is useful for examining what works well and what does not. Voluntary management systems (basically common pool management) are in place in parts of the USA, and they have not managed groundwater well in conditions of scarcity. Court mandated management systems have worked very well but are very costly to create (both in time and money necessary to carry out court cases). District management systems, with a clear mandate and the necessary power to control and monitor pumping have worked well as have statewide administrative systems. At the risk of sounding simplistic, any groundwater management system, in order to be effective, will have to be able to regulate pumping (with permits, well spacing, limits on well size and other means), collect data to determine water availability and the rate of drawdown, and provide infrastructure (for example barrier wells or spreading basins). These are things one can learn from the USA experience. Having said that, however, the USA experience also shows how rigid permit systems can be dysfunctional. Unless administered with flexibility –the flexibility to take into consideration changing geologic and social conditions, and unless administered with local stakeholder input such systems become rigid and are susceptible to cooptation by the same interests that can come to dominate groundwater management in other types of management systems.

The USA experience also provides other lessons on how not to manage groundwater. First, in a water rights system which puts primary emphasis on property rights and money (the ability to drill new wells) above other things (as is the case in many parts of the USA), we can expect that powerful interests will dominate water use and availability. People living off shallow wells lose in such a system if they cannot afford to drill new wells. Such a system will cause conflicts in countries that place some societal values above property rights and money. Second, water management *reforms*, will not work if they are dependent on the goodwill of local pumpers or managers who are beholden or under the influence of powerful local interests. When *management districts* have been proposed in the USA that threatens powerful local interests, they have usually been

defeated or resulted in the creation of districts that have no authority to regulate pumping. Such reforms are false reforms, and will only allow the continuance of the domination of groundwater use by powerful interests who benefit from the *status quo*. For this reason, poor reform is worse than no reform. Third, treating water like a commodity, like any other commodity, ignores the important role water plays in a society and culture. In the USA this is exemplified by the loss of farming communities where water has been poorly managed, and by the trend toward marketing water in arid areas dependent on agriculture. Some communities may decide that a rural, agricultural setting is a desirable environment. Groundwater management systems that give primacy to markets (allowing unrestricted transferability to the highest bidder), will not protect these other values. In the American Southwest farms are being converted to subdivisions at a rapid rate, and the communities being impacted have little when any power to plan a different future. In short, water marketing and an over dependence on property rights ignore other important societal values.

7 SOME CONCLUDING SUGGESTIONS

All of the points above suggest components of an ideal type of groundwater management system. First, systems, like those in the USA, that rely on property rights alone or which set up administrative arrangements that do not take into consideration social conditions, or incorporate changing geologic and human conditions are bound, eventually, to prove dysfunctional when resources become scarce. Water use and management is a human rights issue when it is denied from those that need it to lead productive lives. Management systems should take into consideration of all the people who have a stake in the management of the resource. Second, management systems need to be rigid (with the powers to enforce policy) yet flexible. This suggests management systems should have the authority and power that usually can only be vested by a central government but with a governing body directed by local or regional stakeholders. In this context *stakeholder* should be defined broadly and include everyone with an interest in water management –water impacts the entire community; the entire community should have a right to participate in decision making impacting water use. Finally, the point should be made that there is no *correct* way to manage groundwater. By this I mean what is good management in one place may be poor management in another. Overdrafting can make sense when groundwater basins are non-rechargeable. Salt-water intrusion might make sense to mitigate land subsidence. In one community small farmers might want to be bought out by firms who will drill deep tube wells that dry up their wells. In another community this may not be the desired course. Locally based decision making backed by central authority can allow for this kind of flexibility.

These are simple principles which, for the most part, have not been followed in the USA. They would improve groundwater management everywhere.

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