The Professional Report Committee for Lauren Faye Avioli
Certifies that this is the approved version of the following report:

A New Phase in Water Resource Allocation: The Case for Groundwater Markets in Texas

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ______________________________
Michael Oden

____
Katherine Lieberknecht

A New Phase in Water Resource Allocation: The Case for Groundwater Markets in Texas

by

Lauren Faye Avioli, B.A.

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Community and Regional Planning

The University of Texas at Austin

May 2013

Acknowledgements

I would like to offer my thanks and gratitude to Stefan Schuster, P.G., who not only introduced me to the concept of water markets, but also helped get me started when this report was just a nascent idea. I would also like to thank Professors Michael Oden and Katherine Lieberknecht for their insightful comments and guidance along the way.

Abstract

A New Phase in Water Resource Allocation: The Case for Groundwater Markets in Texas

Lauren Faye Avioli, MSCRP

The University of Texas at Austin, 2013

Supervisor: Michael Oden

This report explores the application of a market framework to allocating water resources, with a specific focus on groundwater resources in Texas. Water markets have been touted by economists as an efficient and effective means of reallocating a scarce natural resource and have been implemented in various forms across the western United States. This report discusses the characteristics of water markets that allow them to efficiently allocate water resources as well as the need for institutional oversight to address negative externalities, including environmental and third party impacts. A description of Texas law and regulation of groundwater resources is also given and analyzed in the context of establishing widespread groundwater markets in the state. Several case studies, both in Texas and in other western states, are also analyzed to determine best practices for the creation of a statewide system of groundwater marketing. The report concludes with several recommendations based on these case study analyses and in light of the current legal and regulatory obstacles to widespread water markets in Texas.

Table of Contents

List of Tables

List of Figures

Introduction

"We never know the worth of water, til the well is dry." – Thomas Fuller

In Texas, and across the American Southwest, water is a highly valued resource – and one that is subject to increasing demands and scarce supply. The great dam building era of the twentieth century has come to a close, with most of the best sites already built upon and budget concerns making federal financial involvement in these large scale projects unlikely. As opportunities for new supply projects become few and far between, the population of the Southwest – and its demand for water – continues to grow. Compounding the problem of delivering water to those who need it are projections of increased periods of drought that are both more severe and more frequent. In such a setting, alternative means of allocating water are needed. Water marketing is one such alternative and has been advanced by economists for several decades as an efficient solution to the problem of allocating an increasingly scarce resource, avoiding the need for large new supply projects or extensive regulatory regimes. However, although water marketing is gaining a foothold in the water allocation schemes of the Southwest, it has yet to be extensively implemented in Texas.

This professional report explores the possibility of employing water markets as a viable means of water allocation in Texas. Though the marketing of surface water could also be more widely implemented throughout the state, only transfers of groundwater are considered in this report.

Despite the ubiquity of groundwater use in Texas, formal groundwater markets do not exist outside the Edwards Aquifer region of Central Texas. Given the potential of groundwater marketing systems to meet growing demand, some assessment of how this system, and others in the Southwest, function should be made to determine if groundwater markets could be introduced elsewhere in the state. To that end, this report seeks to answer the following question: given the current laws and regulations governing groundwater in Texas, what would a viable statewide system of groundwater marketing look like? To answer this question, this report examines four regulatory and marketing frameworks as case studies to determine best practices: the Edwards Aquifer Authority in Central Texas and the three western states of Arizona, New Mexico, and California. Assessments of these systems consider the extent to which they afford protections for third parties and the environment, and are limited to intrastate transfers of groundwater. Analyses of the case studies are used to determine best practices for instituting a groundwater marketing system in Texas. The application of these findings to Texas focuses only on major aquifers in the state and recognizes that there is considerable hydrologic, geologic, cultural, and economic variation among Texas aquifers.

In order to determine what a viable groundwater market for Texas might include, this report first defines what an efficient market for water is and discusses the benefits and drawbacks of using this method to allocate water resources. Chapter One provides an overview of the economic concepts underlying water marketing, including the requisite characteristics necessary for the formation of a market system in this unique natural resource. The shortcomings associated with markets for water are also discussed, including the tendency for market failures to result in negative externalities that impact both third party water users and the environment.

To understand how a groundwater market might fare in Texas, a discussion of the current legal and regulatory regimes governing the use of the resource is required. Chapter Two provides a brief history of water law in Texas, with a special focus on laws and policies relating to groundwater. State water planning efforts and attempts at regulation are also discussed, with an assessment of how these policies and laws hinder or facilitate the formation of efficient water markets in the state.

The first case study analysis is discussed in Chapter Three, which focuses on the Edwards Aquifer Authority (EAA) in Central Texas. This authority oversees the only formalized market in groundwater in the state of Texas. The chapter describes the creation of the EAA and the rules governing its permitting process, and analyzes the authority's trades to date in order to assess the market's overall activity.

Because the EAA's jurisdiction is so limited and its statutory mandates so unique, other regulatory and legal systems of water marketing are also considered. The first of these out-of-state case studies is Arizona, where groundbreaking legislation passed in 1980 redefined the regulation of groundwater and fostered trades within defined management areas. As in Texas, Arizona relies heavily on groundwater resources and manages these resources under a different legal regime than surface water. Thus, the Arizona experience provides important lessons for Texas in statewide regulation of groundwater resources in a state where groundwater and surface water remain legally separate.

New Mexico, also heavily reliant on groundwater, boasts a highly centralized and long standing system of groundwater management. The New Mexico system stands in marked contrast to the current regulatory framework in place in Texas, putting all authority in groundwater permitting and use in the office of the State Engineer and managing groundwater and surface water conjunctively under the same doctrine of prior appropriation.

The final case study, California, possesses its own unique approach to groundwater use, employing a correlative rights system in which all overlying landowners have equal access to and use of the aquifer under their properties. California also uses some of the same tactics employed in Texas, combining this correlative approach with the more common prior appropriation doctrine for non-overlying users and employing a more decentralized management system of localized regulatory districts.

Finally, Chapter Five synthesizes these case study analyses into several recommendations for initiating an efficient market system in groundwater in Texas. These recommendations include the need to eliminate the rule of capture doctrine in favor of a rule of law that is more amenable to establishing private property rights in water and adjudicating water rights for aquifers using a proportionate or shares-based system. The current localized framework of groundwater conservation districts should be maintained as primary implementers of the new water markets, with the Texas Water Development Board acting as a statewide clearinghouse of information on water offered for sale or lease. Additionally, protections for the environment and third parties should also be included to mitigate negative externalities associated with groundwater trades.

It is important to note that while water markets can be successful at mitigating water allocation issues, they are not a panacea for water scarcity issues; a mix of other approaches (including conservation and supply development) will still be needed to craft a sustainable solution to water allocation problems. They do, however, provide the flexibility to allow for reallocation to different uses – an important characteristic as municipal demand grows and agricultural demand declines in much of Texas, and the Southwest in general.

THE LOOMING WATER CRISIS IN TEXAS: THE NEED FOR NEW SOLUTIONS

One of the fastest growing states in the country, Texas is also the second most populous state (US Census, 2011b). Texas is also one of the driest states in the nation ranking 34th in terms of average precipitation over the period 1971 to 2000 (Current Results, 2004). In fact, Texas has experienced four severe droughts since 1980, some lasting multiple years. Research and modeling on climate change suggest that droughts will continue across the state into the future, increasing in both frequency and severity (C2ES, 2012). Thus, Texas is poised for a perfect storm of rising water demand and decreasing or uncertain water supply, making it a prime candidate for exploring alternative methods of water allocation.

The Rising Demand for Water

Texas's population has increased by over 10 million since 1980 and is expected to add over twenty million more residents by 2060 (TWDB, 2012). The state is now home to three of the top ten and six of the top twenty largest cities by population (US Census, 2011a).

As municipal water demand grows as a result of this explosive population growth, energy production is also thriving. With multiple highly productive shale formations in the state, the heavily water-intensive process of hydraulic fracturing (or fracking) of oil and gas deposits is becoming ever more widespread. Demand for water for fracking rose 125 percent from 2008 to 2011 to total 81,500 acre feet (Tinker, 2012). While industry anticipates this rapid growth rate to level off sometime in the 2020's (Tinker, 2012), there is no question that this method of oil and gas production represents a substantial portion of the state's water demand.

Since the 1950s, groundwater has provided approximately 10 million acre feet per year to Texans. In 2008, groundwater accounted for 60 percent of all water used in the state. 80 percent of this groundwater was used for irrigation and 15 percent for municipalities (TWDB, 2012).

With increases in population come increases in municipal and industrial demand. In fact, demand is projected to increase through 2060 across all use categories, with the exception of irrigated agriculture (Figure 1). Currently, municipal use comprises roughly 27 percent of total demand; this is projected to increase to just over 38 percent by 2060. Irrigated agriculture comprised 56 percent of water demand in 2010 and will decline to roughly 38 percent by 2060 (TWDB, 2012).

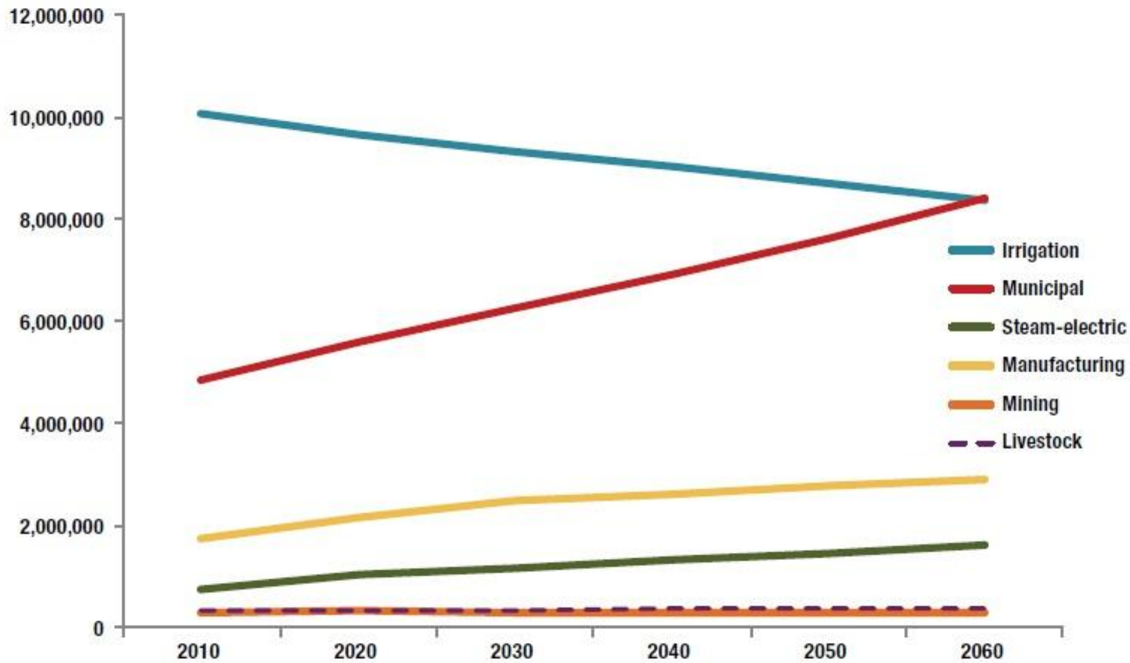


Figure 1: Water Demand Projections by Use Category (Acre-Feet Per Year) (TWDB, 2012, p. 137)

The Falling Supply of Water

Precipitation is highly variable across the state, with parts of east Texas receiving over 55 inches of rain annually and parts of far west Texas receiving less than ten inches. Compounding this lack of precipitation in the drier portions of the state is relatively high rates of evaporation: except in the eastern quarter of the state, evaporation exceeds precipitation, creating semi-arid to arid climate conditions (TWDB, 2012).

Climate modeling suggests that temperatures may rise over the next 50 years, from two degrees between 2020 and 2039 up to four degrees between 2040 and 2059. Further, precipitation may decrease beginning in the middle of the century, suggesting that Texas could experience severe droughts beginning in the mid-twenty-first century that rival or exceed the 1950s drought of record (TWDB, 2012).

Often, drought conditions lead to an increase in the amount of groundwater pumped, as groundwater sources replace depleted surface water resources. In the face of these climate projections, the TWDB also expects groundwater supplies, which totaled about 8.1 million acre feet per year in 2010, to decrease 30 percent to about 5.7 million acre feet by 2060, mostly due to depletion of the Ogallala Aquifer and restrictions on pumping to prevent land subsidence in the Gulf Coast Aquifer (Figure 2).

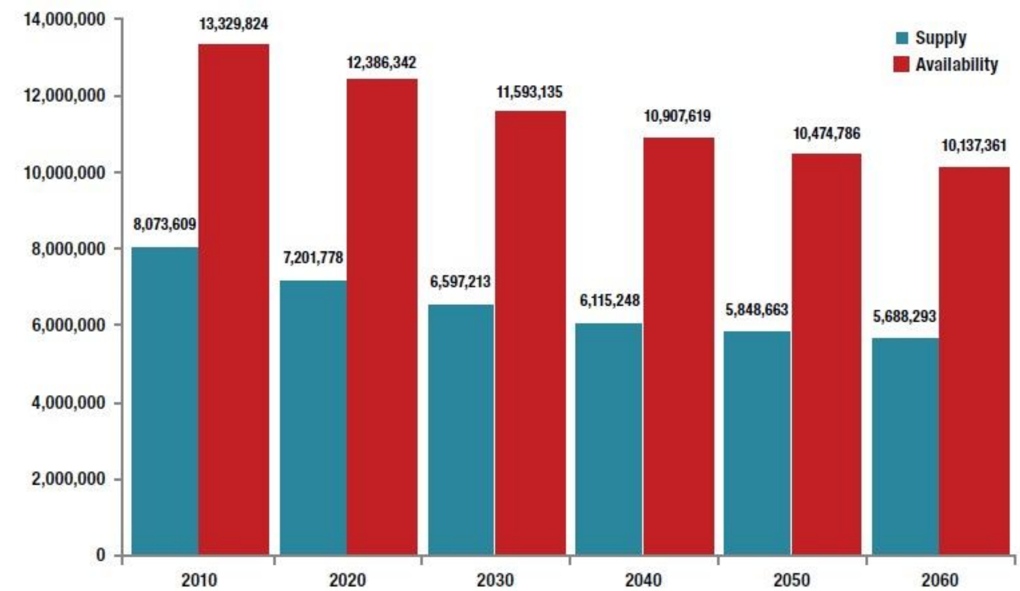


Figure 2: Projected Existing Groundwater Supplies and Groundwater Availability[1] Through 2060 (Acre-feet Per Year) (TWDB, 2012, p. 166)

[1] Groundwater availability differs from groundwater supply in that supply measures only what is available for use given current infrastructure, legal, and permitting constraints (TWDB, 2012). Figure 2 shows the decrease of both groundwater supply and availability over the planning horizon.

Water Supply Needs

Given the projected increase in demand and the anticipated decrease in groundwater supply, unmet needs are inevitable. Unmet municipal needs are expected to rise precipitously over the planning period from 9 percent of total unmet need in 2010 to 41 percent in 2060. Other uses are also expected to experience shortfalls throughout the planning period, with irrigation accounting for the largest share of unmet needs through 2060 (Figure 3).

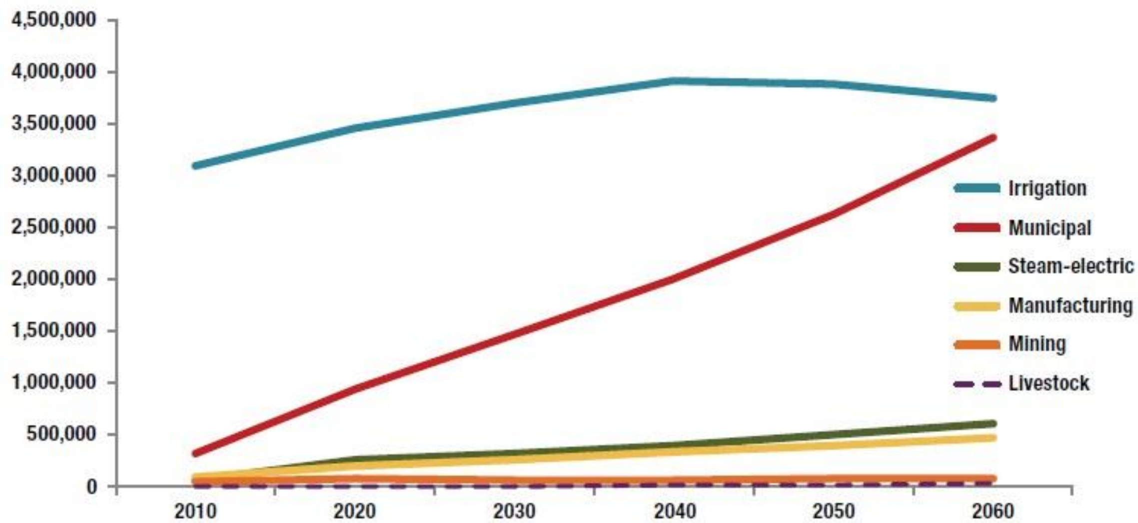


Figure 3: Projected Water Needs by Use Category (Acre-feet Per Year) (TWDB, 2012, p. 179)

As this report will discuss, one way to meet these excess demands is through water marketing. This strategy is not discussed at much length in the 2012 state water plan, from which most of this data on projected demand, supply, and needs were drawn. However, the transferring of water rights can provide the flexibility needed to address changing demands across use categories and the incentive to conserve a scarce resource that will become all the more precious in the face of severe drought and population growth.

Chapter One: Water Markets

Although water has been allocated according to market principles in the past,[2] a broader application of a market framework for water resources has been slow to develop. Perhaps this inertia is due to the inherent difficulties of allowing the market to allocate a common pool resource like water, or perhaps water's central role in sustaining life causes society to be wary of opening a potential Pandora's Box of equity issues with an economically based allocation system.

Whatever the reasons, and despite them, the application of a market framework to the allocation water is gaining traction as a viable option in water resource management in the American West, especially as much of the existing surface water supply is already appropriated and groundwater supply is being mined at unsustainable rates. Indeed, a survey of western states undertaken by the Western Governors' Association found that 75 percent of respondents said water transfers will constitute an important method of allocating water and meeting demand in the future. In Texas, the recent drought has already contributed to a higher demand for water trades: over 1.7 million acre feet of water was traded in mid-drought 2011, compared to an average of 150,000 acre feet per year from 2007 to 2009 (WGA, 2012).

The following chapter outlines the economic argument for efficient allocation of water through a market process and discusses the requisite characteristics for efficient water markets. While many of these characteristics hold true for both surface and groundwater marketing, only groundwater marketing is considered here.

---

[2] Charles W. Howe (Anderson & Hill, 1997) documents several instances of historical water marketing, including auctioning of irrigation rights in sixteenth century Spain and century-old, but still active, Chilean markets. Even in the United States, water rights were frequently traded among miners during the California Gold Rush (Anderson & Hill, 1997).

For purposes of this analysis, a viable or efficient groundwater market is one that exhibits flexibility and efficiency in groundwater allocation (either through transfer of water rights or quantities of water itself), and that also incorporates measures to mitigate negative externalities to the environment and third parties, thereby minimizing or eliminating groundwater overdraft.

BASIC ECONOMICS OF EFFICIENT WATER MARKETS

Water marketing, or water trading,[3] generally refers to the permanent or temporary transfer of water between users for an agreed-upon price. A permanent transfer of water rights to a buyer is known as a "sale," while more temporary agreements are classified as "leases." Buyers and sellers may also choose to enter into an "option," whereby the seller retains the use of the water right until a predefined event occurs – such as a drought – in which case the buyer may then temporarily use the water right (Griffin, 2011).

How Markets Can Lead to Efficient Allocation of Water

A neoclassical approach to the issue of water marketing suggests that a market system in which water users are able to buy and sell water freely most efficiently allocates this scarce resource by ensuring that the water is used by those who value it most and that less water is wasted by users overall. Indeed, research shows that in areas with widespread irrigation and a scant water supply, large gains in economic efficiency

[3] James A. Swaney (1988) makes the argument that the difference between "water marketing" and "water trading" is a distinction of the diversion point of the water: "water trading" deals with water that is left in place by the original user and allowed to flow to the buyer for withdrawal, while "water marketing" deals with water that has been withdrawn by the original user (33). For purposes of this report, I will make no differentiation between water traded and water marketed, referring to both types of transactions merely as "water marketing."

are possible through better conservation and reallocation among users (Hearne and Easter, 1995; Vaux and Howitt, 1984).

Pricing to Reflect Scarcity

A central tenet of this argument for the efficient allocation of water via market mechanisms is founded on pricing: water prices have remained low overall and agricultural users often receive water at highly subsidized rates compared to their municipal or industrial counterparts (Anderson and Snyder, 1997; Griffin, 2011; Swaney, 1988). To the neoclassical economist, a framework that recognizes the scarcity of water through a more realistic pricing system would allocate water more efficiently by curtailing wasteful use and redirecting supply to those who value it most. While the most obvious solution may seem to be to alter the current pricing system to better reflect the scarcity of water, rather than institute a market system, the political clout associated with entrenched agricultural and utility interests has often stymied these efforts. Thus, a better way to achieve efficient water allocation may be to change the incentive structure so that users themselves support reallocation efforts (Easter, 1998) – that is, through a market structure. As Easter argues:

> …if water markets are established where water is scarce, then users can buy and sell water and the whole incentive system is changed. When users can benefit from the reallocation, they are willing to sell water or pay higher prices for new supplies. (3)

Paying a higher price for water, one that better reflects the scarcity of the resource, would address the inefficiencies that develop when price is distorted which result in the overuse or waste of water. Indeed, "[w]hat is seen as waste or inefficient water use…is simply the users' rational response to low water prices…[b]ut users can afford to be wasteful only when water is cheap" (Anderson and Snyder, 1997, p. 10).

Simply put, by utilizing a framework with a more realistic price for water, people will use less water to meet their needs as water consumption becomes more expensive.

Hansen's (2012) model of optimal groundwater management in Albuquerque, which incorporates scarcity costs into the management scheme, shows that when prices reflect the scarcity of the resource, huge savings result. Under this optimal management scheme, the net present value of the aquifer is maximized over time so that supply is preserved as long as use of the resource is economically efficient. Employing this approach over a 200 year planning horizon, assuming 1.8 percent growth in population and a 1 percent increase in demand, yields a savings of 391,000 acre feet at the end of the planning horizon, enough water for 70,000 people over 100 years. These savings amount to $156 million, or $398 per acre foot. Because the pricing adequately reflected the scarcity of the resource, per capita water use was reduced 26 percent by the end of the planning horizon and 200 more feet of water was left in the aquifer than would have remained under the status quo management scheme, where scarcity costs were not factored into pricing decisions (Hansen, 2012). Again, this model has direct implications for water marketing as a fundamental tenet of establishing a groundwater market is ensuring that price accurately reflects supply and scarcity of the resource.

Flexibility in Reallocation

While the pricing implications of markets make such an approach attractive in terms of curtailing waste, the system's flexibility in reallocation is just as instrumental in assuring efficient use.

In recent decades, water use in the West has been characterized by transfers from agricultural to municipal use. While irrigated agriculture still accounts for approximately 70 percent of water use in the western United States (WGA, 2012), states from California to Texas are projecting declines in agricultural consumption and significant increases in municipal consumption over the next several decades. Unlike extant regulations in some states that restrict the user's ability to change the type of use associated with a water right, a market system that allows water trades among different types of users would enable water to be easily transferred from agricultural to municipal or industrial use, where demand is greater.

That this flexibility can translate into substantial cost savings and reduced consumption has been demonstrated both in real market activity and in modeled scenarios. Chang and Griffin (1992) evaluated 20 years of surface water market activity in Texas's Lower Rio Grande Valley, discovering that estimated benefits to purchaser municipalities far exceed the costs or tradeoffs incurred by agricultural sellers in the water transfers. Chang and Griffin's findings echo another, previous analysis conducted by Griffin (1990) in which an analysis of municipal water acquisitions by the average Texas urban area revealed that the values of this water to the municipality ranged from $0 to $4,000 per acre foot, with the highest value scenario incorporating high population growth rates, reflecting the strong influence that population growth can have on making purchased water rights extremely valuable (Chang and Griffin, 1992).

In California, Howitt (Easter et. al, 1998) determined that an option agreement between the agricultural Palo Verde Valley Irrigation District and the municipal provider Metropolitan Water District ultimately conserved 114 million cubic meters (92,421 acre feet) of water by fallowing 20,215 acres (only 25 percent of their land) for only two years.

These fiscal and conservation savings have been demonstrated not only in the United States, but in other countries as well. Hearne and Easter's (1997) analysis of gains-from-trade in two Chilean river basins utilizing water marketing strategies found that substantial gains were realized by both buyers and sellers, with buyers obtaining higher economic rents than sellers. Further, the authors postulate that while the overall growth seen in Chile's agricultural output over the 1980s and mid-1990s can be attributed to several reforms (including liberalization of trade and privatization of land), the ability to market water also played an important role, especially in expanding the irrigated agricultural sector – which grew in the absence of new investments in irrigation infrastructure (Hearne and Easter, 1997).

Although water marketing is not quite a novel idea by this time, it still has yet to be systematically employed across the globe; thus, there is a lack of definitive, comprehensive datasets on water transfers and measured benefits that accrue from them (WGA, 2012). Because of this, much of the quantitative data supporting water market efficiencies can be found in the literature on modeled water market scenarios, such as Vaux and Howitt's (1984) work on modeled gains in California water markets. In this study, the pair compared gains from a water marketing scenario to gains from a base case without water marketing, finding that one could expect significant benefits as well as decreased consumption statewide into 2020. Under the water marketing scenario, which includes a groundwater management strategy to prevent a race to the pump and rapid aquifer depletion, the model shows a substantial volume of trades from agricultural to municipal use, with total statewide use declining by five percent. Further, no new supply projects are demanded, given the flexibility in allocating existing water resources. Both buyers and sellers benefit: urban users are considerably better off than under the base case scenario, with cheaper supply and more plentiful quantities, while agricultural users voluntarily use less water, preferring instead to sell their supply because water prices outweigh the agricultural returns from irrigation. Ultimately, the water market scenario leads to a 40 percent increase in statewide benefits in 2020 over 1995 levels.

Additionally, the model shows that municipalities may possess excess capacity, indicating that the previous lack of water trading opportunities has caused cities to "invest prematurely in water supply facilities" and that "[f]rom an efficiency standpoint, current institutions tend to promote uneconomical water use and exacerbate political competition for scarce water supplies" (p. 790).

The Need for Well-Defined Private Property Rights

To realize these benefits, a water market must be predicated on the existence of well-defined and enforceable private property rights. An ideal construction of property rights incorporates the following:[4]

1. Universality: the property rights system encompasses all of the resources it was designed to oversee so that no resources remain unallocated; all rights are quantified
2. Exclusivity: all costs and benefits associated with the use of the resource accrue only to the property rights holder
3. Transferability: any property right holder can transfer his right to any other party voluntarily
4. Enforceability: property rights holders must be secure in the knowledge that their rights are protected from encroachment or seizure.

When individuals obtain enforceable, transferable, and exclusive rights to a resource, they are more apt to use that resource effectively. Because all benefits and costs associated with the resource accrue to the property owner, squandering the resource represents a financial loss (Griffin, 2011).

[4] Adapted from Griffin, 2011, p 89.

In the case of markets for groundwater, rights holders must be secure in the knowledge that they have access to the amount of water afforded them by their rights and that violators who appropriate water to which they do not have a right will be held accountable (Whitford, 2007). Additionally, a property rights holder must be certain of the quantity, quality, location, and timing of water available, must be secure in the knowledge that his right will not be encroached upon or unreasonably impacted by another, and must be allowed to transfer the right in response to changing conditions (Easter, et.al, 1998).

For groundwater markets, failure to comprehensively establish and enforce private property rights can result in overdraft (in which water is pumped at a rate greater than the aquifer is recharged) and inefficient use as users race to extract as much water as they can before their neighbors do. Concurrently, establishing private property rights in water for only a portion of an aquifer presents the same problems: pumping by non-rights holders will undermine the system's security and reliability by increasing the uncertainty that a rights holder will be able to exercise his right over time.

When private property rights are established correctly, overdraft can be mitigated or even eliminated. In California's Tehachapi Basin, over pumping led to extreme overdraft conditions such that withdrawals exceeded recharge by 60 percent in 1960. The water table fell roughly 70 feet per year during the 1950s and three feet per year during the 1960s. Property rights were adjudicated in the basin in the early 1970s, and water levels had ceased declining by 1997, with well levels recovering by as much as 50 feet (Anderson and Snyder, 1997).

Externalities and the Need for Institutional Oversight

Groundwater, like surface water, can be characterized as a common pool resource. It is a rival good and only excludable to the extent that only pumpers overlying the aquifer can access the water. Additionally, water's "flow through our environment links humans [and to some extent, wildlife] in an array of complex interrelationships" that inevitably results in significant third party effects not adequately internalized in transactions on the unfettered market (Griffin, 2011, p. 50). To address these market failures – which encompass both environmental and equity issues – some form of regulatory oversight is needed.

Overdraft and its Effects on Third Parties

When water is pumped from a well, a cone of depression is created as the water level in the aquifer surrounding the well drops. When the amount of water pumped is large enough, this drawdown effect can impact neighboring users by requiring them to drill farther into the aquifer to obtain water. The farther down a user must go to obtain water, the more expensive the water will be to bring to the surface. Thus, one user's pumping can have negative economic effects on the ability of other users to pump. Within an unfettered marketing framework, a pumper may withdraw water to which he is entitled and sell it to a willing buyer without considering the economic impact he may be imposing on neighboring well owners through his pumping. The externalization of these costs undermines the security against encroachment that is required of an efficient property rights system. A pumper's impact is not necessarily limited to neighboring wells, however. In fact, the effects of groundwater transactions can have far-reaching social and economic effects when enough water is at stake.

Intergenerational equity can also be left out of decisionmaking in markets that substantially discount future benefits in favor of present value. In areas like the Ogallala aquifer region of the Midwest and Texas panhandle, the benefit present users receive from pumping groundwater is clearly valued more than the benefit that might accrue to future generations, as evidenced by the mining of groundwater at increasingly rapid rates. Research suggests that a market framework that takes future benefits into account through regulatory oversight involving conservation methods and managed demand extends the life of the aquifer and increases potential welfare gains, achieving efficiency by considering costs and benefits through, rather than at a single point, in time (Hansen, 2012).

As previously mentioned, the shift from agricultural to urban water use has become a growing trend. The removal of large amounts of water from rural, agricultural areas can have significant secondary economic impacts through a multiplier effect, leading to losses in income and employment for industries that serve the agricultural sector (Anderson and Hill, 1997). In states where water rights are appurtenant (i.e. attached) to land, the fiscal repercussions can be felt even before groundwater is pumped as acres of land are bought by remote municipalities and fallowed; this problem became especially severe in Arizona and California over the 1980s and 1990s (Woodard, 1989; Easter, et.al., 1998). To combat these effects, over a dozen western states have incorporated some form of public interest considerations into statutes involving water appropriations or transfers (Ingram, 1992).

The Public Trust Doctrine

In light of the sweeping effects of water transfers, the public trust doctrine has gained a foothold in water allocation dialogue. Stemming from the Roman concept that waters are the common property of all (*res publica*), the public trust doctrine was widely employed in the nineteenth century and later formed the basis for the preeminent role the federal government played in the financing of countless large scale supply projects (Anderson and Hill, 1997). The doctrine has imbued the water policy of most western states, and is evident in state constitutional language that references public waters held in trust, traditionally for the purposes of navigation, fishing, and commerce (Ingram, 1992; Anderson and Hill, 1997). Several states have broadened the definition of public interest to include wider considerations of social and economic wellbeing, as well as environmental interests.

The implications of the public trust doctrine can impede formation of water markets. Laws based on the doctrine may mandate forfeiture for holding water rights for future sale. Concurrently, most states adopting the public trust doctrine also have provisions for allowing water to be used only for "beneficial uses," but define a beneficial use so broadly that only the most egregious waste is deemed unbeneficial (Anderson and Hill, 1997), whereas a market system would allow water to move from lower to higher-valued uses, preventing waste.

Although the public trust doctrine does present some obstacles to the implementation of water markets, it does provide a mechanism for incorporating traditionally unacknowledged considerations into the water allocation equation. Rural communities seeking to protect themselves from the potentially devastating effects of large-scale water transfers can invoke the concept of public trust to incite a dialogue about the true costs of transferring water to a distant municipality.[5] Incorporating these considerations should not provide an insurmountable obstacle to water trades, but rather ensure that only those trades that are most beneficial take place, thereby increasing the overall efficiency of the system.

---

[5] In cases where sufficient third party effects are in place, water markets can actually increase rural incomes. In South Australia, for example, *intra-basin* water trades alone added $32.6 million to rural incomes over the period 1987-1991 (Anderson and Snyder, 1997).

Externalized Environmental Effects

Groundwater can play a central role in sustaining aquatic habitats and there are significant environmental concerns that should be acknowledged in any groundwater marketing framework. As in the case of third party effects however, environmental impacts often go unnoticed in water transfers unless specific provision is made for them. Common environmental externalities associated with groundwater use include aquifer compaction and land subsidence, negative effects on spring flow – which can contribute to the more commonly discussed impacts on riparian systems – and water quality issues. For each of these issues, groundwater overdraft is the main culprit. In a marketing system where environmental needs are quantified and given weight, overdraft would therefore be managed (Kelly, 2004).[6]

Several states have recognized the need to incorporate environmental considerations into water appropriation decisions, quantifying environmental flow needs and expanding the definition of beneficial use to include instream uses (i.e. water left in place for ecosystem and recreational needs). While acknowledgement of environmental needs is more pronounced in surface water markets, the importance of including environmental considerations is paramount in achieving an efficient groundwater market as well.

---

[6] Water markets have also been shown to reduce environmental impacts while providing a cheaper alternative to other administrative or technological treatment options. Weinburg et. al. (1993) modeled improvements in adverse environmental effects from agricultural drainage in the San Joaquin Valley, showing that in an open water market scenario farmers enjoyed larger net benefits ($404.64 versus $370.16) and reduced drainage, with any reductions in crop yield offset by efficiency gains. Archibald and Renwick (1998) determined that a market-based approach to meeting water quality standards in the Sacramento/San Joaquin Delta would provide at least $225 million in net social benefits more than an administrative regulatory approach and cost only about a third as much.

Institutional Oversight Needed to Correct Market Failure

As is the case with most market failures, some form of regulatory oversight is needed to address these externalized third party and environmental effects and ensure that a market for groundwater does in fact efficiently allocate the resource. Though some research has attempted to show that regulatory frameworks do not provide significant benefits over an unfettered market system (Gisser and Sanchez, 1980), important equity and environmental costs such as those discussed above were not taken into account. Indeed, institutions can play an important role in a water marketing system through not only internalizing these usually externalized costs, but also in lowering other transaction costs that could discourage water transfers from taking place. While the inclusion of environmental and third party impacts can increase the costs of a water transfer, institutions can lower other transaction costs associated with legal challenges by third parties, constructing means of conveying the water, information shortfalls, and enforcement of water rights (Easter, et. al, 1998).

Any overarching water market institution must be a facilitator, however, leaving the water rights in the hands of the users, treating each water interest objectively, and refraining from price setting. Institutions should act as unbiased water brokers, taking care that transfers do not impose uncompensated costs on third parties through a system-wide evaluation of costs and benefits. Finally, government institutions are needed to adjudicate the initial water rights and to enforce them in the future. Without enforced water rights, a user who wants to secure more water can simply divert (or pump) more, but this increased extraction can damage existing users (Easter, et. al., 1998).

Thus, the concept of an optimally efficient water market does not necessarily equate to a laissez faire market but rather one with inherent externalities that necessitates some form of regulatory intervention to ensure adequate enforcement of rights, internalization of third party costs, and acceptable levels of transaction costs.

Chapter Two: Texas Water Law and Policy

Currently, water law in Texas is not conducive to water marketing, and is especially adverse to the establishment of markets in groundwater. Reliance on an antiquated common law doctrine and a reluctance or inability on the part of local districts to manage groundwater pumping contribute to the lack of viable groundwater markets in the state, save for one region in Central Texas. This region's groundwater market, which encompasses the southern portion of the Edwards Aquifer, is discussed at greater length in Chapter Three.

THE RULE OF CAPTURE DOCTRINE

Like most states, Texas first focused its attention on the establishment of systems of governance and appropriation of surface water before turning to groundwater sources. The nearly three hundred year head start surface water law has enjoyed means that efforts at establishing effective systems of allocation for surface water that facilitate trading are more advanced, while comparable groundwater regulation is just beginning to evolve (Easter, et. al., 1998).

In Texas, as in most other western states, groundwater and surface water are managed according to different legal and regulatory systems. For surface water, the concept of prior appropriation (or "first in time, first in right") is employed. Harkening back to the public rights doctrine, prior appropriation considers all surface waters the property of the State, and the right to divert and put the water to beneficial use must be obtained from the government (Texas Water Code, §11.002(4)). The prior appropriation doctrine is incorporated into the regulation of surface water in all seventeen states west of the Mississippi River (Gopalakrishna, 1973).

Though Texas employs a popular legal doctrine in appropriating surface water rights, it makes a substantial departure from common contemporary groundwater law in its continued promulgation of the rule of capture in governing groundwater rights. Also known as the "absolute ownership" doctrine or the "English Rule," the rule of capture stems from English common law, and during the nineteenth century was used by most western states to inform groundwater law. Under the rule of capture, a landowner is entitled to the water underlying his property and may pump as much as he wishes. As long as the landowner is not acting maliciously, he may pump unlimited quantities of water despite the harms this may cause neighboring landowners. Case law in Texas has placed minimal restrictions on the rule of capture, requiring merely that the water pumped cannot be "wantonly or willfully" wasted (Chalmers, 1974, p. 87), and that pumping does not cause subsidence of the overlying land.

Texas water law divides groundwater into two categories: water that flows through "definite underground streams" and water that does not (also called "percolating waters"). The rule of capture applies exclusively to the latter class of groundwater, and for purposes of Texas groundwater regulation, underground water is presumed to be percolating water (Hutchins, 1961).

Under this common law doctrine, though he may pump unlimited quantities of water, the landowner has no right to the water in place. He must first reduce the water to ownership through pumping it to the surface, before he may be said to have a right to the water itself. Thus the rule of capture provides not a private property right in water per se, but rather access to water through a private property right in land (Easter, et. al., 1998).

Once the water is brought to the surface, the landowner may export or sell the water (Griffin, 2011).[7]

In 1904, as most of the eastern United States relinquished the rule of capture for other legal doctrines, the rule was affirmed in Texas with *Houston & Texas Central Railway Co v. East* (Votteler, 2000). In this case, the Texas Supreme Court held that subsurface (percolating) water was the property of the landowner, "a part of, and not different from, the soil" itself (*Houston v. East*, 1904). The Texas court based its decision on an 1861 Ohio Supreme Court case that characterized subsurface waters as so "secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible" (*Frazier v. Brown,* 1861).

The rule of capture was upheld by the court again in 1955 in *City of Corpus Christi v. City of Pleasanton*. However, in his dissent, Justice Wilson expressed dismay at continuing to uphold a rule of law based on so antiquated an understanding of the natural world:

> [The decision made in *Frazier*] overlooked the possibility of advances in knowledge and technique. It is understandable that this rationale should appeal to this court in 1904 but I regret to see us reaffirm it now…especially in view of…the advancement of scientific and legal knowledge and governmental techniques… (Chalmers, 1975, p. 88).

Although the legislature has made some attempts to apply regulations to groundwater use, as will be discussed in the "Legislative Actions regarding Groundwater" section, little has changed regarding the application of the rule of capture in Texas. Currently, Texas is thought to be the only state that still employs the rule of capture in governing groundwater (Votteler, 2000).

---

[7] This method of transferring water is discussed at greater length in the next section.

Implications for Water Transfers under the Rule of Capture

At first glance, the rule of capture doctrine may seem to imply that property owners over an aquifer have private property rights in water; however, this is actually not the case. As previously mentioned, the rule of capture system only provides access to groundwater, not rights to the water itself. Rather, overlying landowners in a rule of capture system enjoy "group ownership of the aquifer's water" (Griffin, 2011, p. 59). This group ownership is characterized by limits on the ability to trade and a lack of restrictions or protections for individual pumping:

- While some exclusion is possible (to the extent that only overlying landowners can withdraw water from the aquifer), overlying landowners are not individually limited to the amount of water they can withdraw, nor are they protected from the adverse effects of others' over pumping;
- Landowners are unable to sell or lease the water while it is still in the aquifer (Griffin, 2011).

The group ownership engendered by the rule of capture system lacks several of the fundamental characteristics that define a private property right necessary for efficient resource allocation. Due to the prohibition on selling or leasing water in place, the transferability of the right is severely inhibited. Further, the benefits and costs of pumping do not accrue solely to the pumper; indeed, the doctrine has been interpreted by the courts as protecting a pumper from liability for all harm to his neighbors save that which was "maliciously" inflicted. Thus, the system also lacks enforceability as one user's rights cannot be protected from the encroachment of others (Griffin, 2011). Simply put, a rule of capture system lacks "the rights to use, exclude [others from using], and transfer" the resource that are so fundamental to an efficient market system (Anderson and Hill, 1997, p. 176).

Within this framework, landowners with access to groundwater have two options when attempting to sell or lease their water: they may sell the water itself, or they may sell or lease their right to access the water.

As mentioned previously, if a landowner overlying an aquifer wants to trade his water, he is statutorily prevented from entering into any transactions that involve water left underneath his property. Therefore, he must pump the water to the surface (reduce the groundwater to ownership) before he can sell it. Once the water is brought to the surface, it can be bought by any party, regardless of whether the buyer intends to use the water on land overlying the aquifer or not. Some practical considerations may limit the field of potential buyers however: since the aquifers themselves cannot be used as a means of conveyance in Texas, the water must be transported via pipeline, canal, or truck so any potential buyers must be within a reasonable distance of some legal method of conveyance (Easter, et. al., 1998).

The second option is made possible by the fact that the right to pump is separable from the owner's property right in land (TWDB, 2003). Prior to this separation, the right to access groundwater was appurtenant to land. Thus sales of the right to pump necessarily involved sales of the land to which the pumping right was attached (this is known as "water ranching" or "water farming"). However, since the right to access water has been divorced from the land, a landowner may sell or lease the right to pump water from his land while retaining ownership of the land itself. This has often taken the form of a municipality leasing the right to pump from a landowner on a long-term basis (Griffin, 2011).

While several of the necessary conditions for an efficient market of the type described in Chapter One are absent from the rule of capture groundwater system in Texas, public and private entities have found ways to buy and sell the water they need.[8] Often, these transfers involve only the rights to pump, but some also involve the purchase of the overlying land.

It is important to note that although the transfer of water does occur in the transactions that are currently taking place, the regulatory framework needed to mitigate the effects of externalities on third parties and the environment is still absent. Thus, these options do not constitute an efficient water market of the type discussed in Chapter One, but rather reflect the need for such a framework by showing that there is a demand for cost effective and flexible ways to reallocate scarce water resources.

LEGISLATIVE ACTIONS REGARDING GROUNDWATER

The more problematic aspects of the rule of capture – such as the limitless ability of a user to pump, regardless of the harm he inflicts on others by doing so – became more pronounced as demand for groundwater increased. While the doctrine was relatively effective in the early twentieth century, as municipal and large-scale agricultural operations began pumping in earnest, the holes in the doctrinal bucket began to leak.

Groundwater Conservation Districts

Recognizing these holes, the legislature amended the Texas Water Code in 1949 to allow for the establishment of underground water conservation districts (or groundwater conservation districts – GCDs), whose statutory purpose was for "the conservation, preservation, protection, and recharging and the prevention of waste of percolating ground water in subterranean reservoirs" (Hutchins, 1961, p. 588). The

[8] For an expansive list of recent large-scale transfer proposals, see Mary Kelly (2004) p 12-14.

establishment of these districts was to be a local affair – initiated with a local petition – signaling the legislature's unwillingness to mount a centralized, state-wide approach to the regulation of groundwater. However, the creation of GCDs is not solely left up to localities: the legislature also has the power to create new districts (Texas Water Code, §36.011), and in fact most districts have been created this way (Lesikar, 2002). In 1997, the legislature recognized that GCDs were to be the primary and preferred method of groundwater regulation in the state (Texas Water Code, §36.0015).

Currently, there are 99 GCDs in Texas (Figure 4), the vast majority of which were established after 1985 (a full 36 years after the law was enacted). 43 of these districts were created after 2000. The explosion in GCDs in recent years highlights the fact that localities are recognizing the scarcity of their groundwater resources and the need for some form of regulation, protection beyond that which the rule of capture provides.

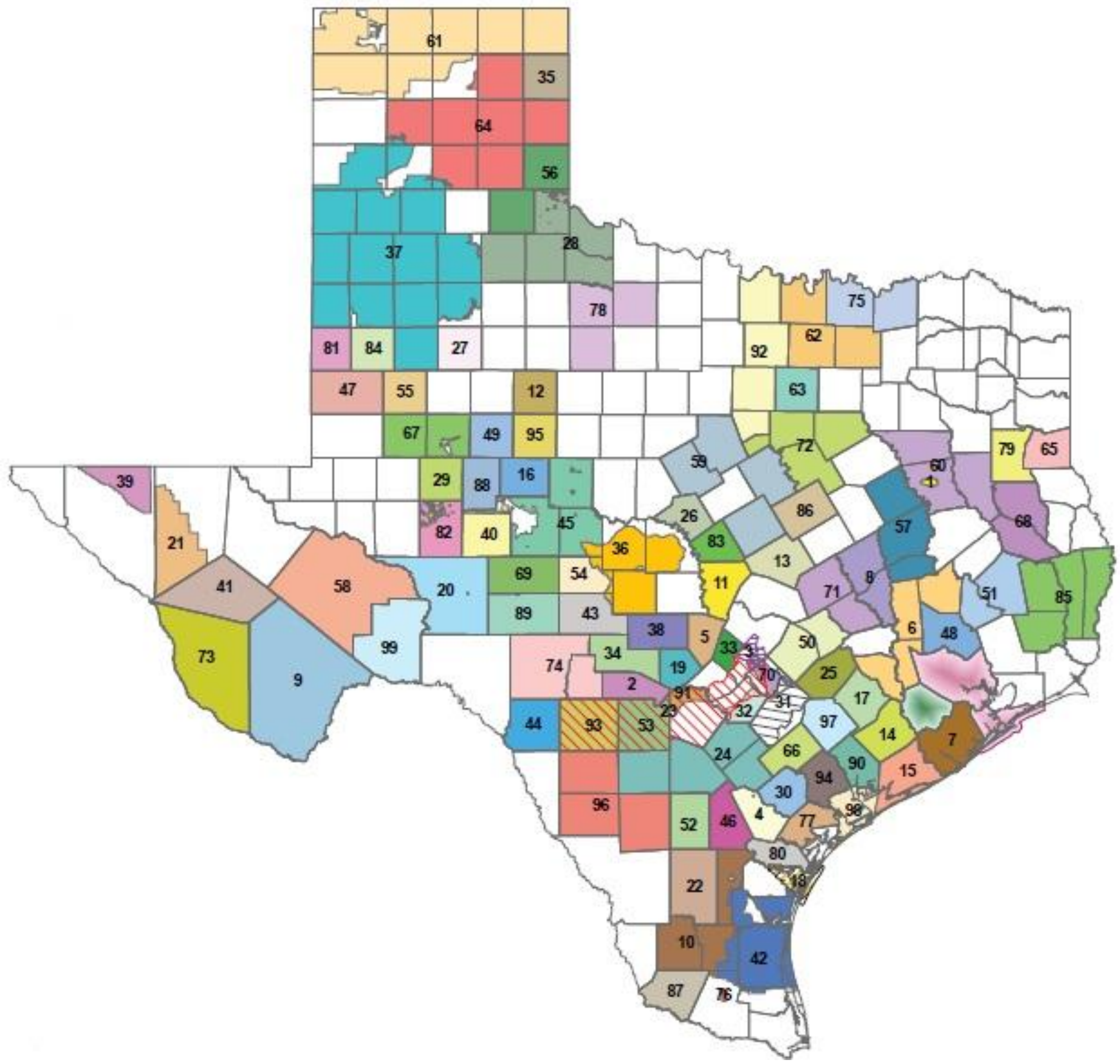


Figure 4: Groundwater Conservation Districts in Texas (TWDB, 2012, p. 24)

To manage groundwater resources, GCDs are required under the Texas Water Code to create and implement a groundwater management plan, register and permit certain types of wells, and record the number of wells and the production and use of groundwater (Griffin, 2011). They may also:

- regulate well spacing and pumping (§36.101)

- acquire through eminent domain land that is necessary for recharge or reuse purposes (§36.105),
- require permits or levy fees for water exported out of the district, (§36.064, 36.122)
- set regulations to mitigate subsidence, degradation of water quality, and waste (§36.101), and
- enforce their rules through injunction and civil penalties (§36.102).

Given these powers, GCDs have the potential to play a substantial role in marketing groundwater resources. Their mandate to permit wells and ability to set pumping caps could be used to establish quantified private property rights in groundwater that could then be traded (Griffin, 2011). However, many GCDs have yet to fully exercise their authority. For instance, though the water code allows a GCD to limit the production of wells,[9] very few have actually set pumping caps (Kelly, 2004). Additionally, the ability of GCDs to levy export fees on water sold to out-of-district buyers could raise transaction costs and discourage some water trades (Griffin, 2011). GCDs may further limit water exports by determining that the buyer does not actually need the water, or that the transfer is otherwise not in compliance with the district management plan or regional water plan (Texas Water Code, §36.122).

If a GCD is predisposed to disfavor the exportation of water out of the district, the provisions of §36.122 can unnecessarily limit otherwise beneficial water trades. Such a predisposition also violates the requirement that a regulatory body must be objective and without bias – a necessary prerequisite for an efficient water market system, as discussed in Chapter One. In 2001, Senate Bill 2 (SB 2) amended the water code to address some of

[9] Limits can be "based on acreage or tract size, a defined number of acres assigned to an authorized well site, acre-feet of water per acre of land, or gallons per minute per well site…" (Griffin, 2011, p. 46).

these concerns. Under SB 2, GCDs are prohibited from promulgating stricter standards for permits to export water from the district than for intra-district transfers. The bill also capped export fees and precluded GCDs from considering alternative supplies available to the out-of-district buyer or the proposed use of the exported water when making permitting decisions (Kelly, 2004).

While these provisions may facilitate beneficial transfers of water to out-of-district areas by lowering transaction costs and removing regulatory barriers, they also threaten to externalize third party costs, for instance by limiting the GCD's ability to take into account lost recharge from the removal of the exported water from the district (Kelly, 2004), or whether the importing region will use the water as efficiently as it might have been used by an in-district buyer (Brock and Sanger, 2003).

Recent Case Law and Groundwater Regulation

Another, potentially severe, limit on GCDs' ability to manage groundwater resources stems from two recent court decisions that have ruled in favor of property owners demanding compensation for unconstitutional takings of their private property as a result of pumping caps mandated by the Edwards Aquifer Authority. *Bragg v. Edwards Aquifer Authority* and *Edwards Aquifer Authority v. Day* both involve farmers who were not permitted to pump the amount of groundwater they alleged was needed for irrigation. The Bragg case, decided in district court in 2010, struck a blow for groundwater conservation efforts as the judge found the plaintiffs were entitled to compensation by the Edwards Aquifer Authority. Two years later, groundwater management suffered an even greater setback when the Texas Supreme Court unanimously reaffirmed the rule of capture, stating that a property owner in Texas does have a right to all the water beneath his land, much as he does to oil or gas deposits, and that this right, moreover, is "a constitutionally compensable interest" (Wilder, 2012). The court then remanded the case to the trial court for further deliberation on the amount of compensation due the plaintiffs, so the full implications of this decision remain hazy. However, these decisions could be potentially lethal to the conservation of groundwater by GCDs, opening the districts up to avalanches of takings claims and lawsuits. Even cities seeking to supplement their water supplies with rural sources could be threatened (ibid). The implications for groundwater marketing could be just as dire as the enforceability of groundwater rights is undermined by an inability to quantify a pumper's water right.

State Water Planning

Following the drought of record (DOR) of the 1950's, the legislature established the Texas Water Development Board (TWDB) to oversee a state-wide water planning process (Griffin, 2011). From this process, nine state water plans, *Water for Texas*, have been published. Following another drought in the mid-1990s, Senate Bill 1 (SB 1) was passed in 1997 and reworked the state-wide planning process, developing 16 planning regions and delegating the water planning to them, echoing the legislature's preference for decentralized water management seen in the initial establishment of the GCDs. Since 1997, the state water plan has been compiled from the 16 regional water plans.

Until the 1997 plan, *Water for Texas* touted large new supply projects as the solution to the state's water needs. With the 1997 installment however, conservation and reuse began to be voiced as tools for managing use of the increasingly scarce resource (Griffin, 2011). The 2012 water plan still recommends several large new supply projects, but conservation, reuse, and technological alternatives like desalination and cloud seeding are also represented in regions' major water management strategies. Water transfers are mentioned, but water marketing is not discussed as a serious option for meeting demand in the latest plan. Currently, the 83rd legislative session is debating whether and how much funding to allocate to the TWDB for the purpose of creating the next water plan (to be published in 2017).

The planning process has also begun to consider the water needs of the environment. Instream flows needed to sustain aquatic ecosystems are more commonly discussed in surface water management, but groundwater management decisions can also impact the environment by affecting the flow of water from aquifer-fed springs. Often, these springs are directly linked to surface water flows, feeding nearby rivers and creeks. They also provide habitats themselves for a variety of animal and plant species. Under the rule of capture framework of course, neither springflow needs nor safe yield[10] are quantified. Within GCDs, however, the opportunity exists to incorporate environmental needs into the regulation equation. House Bill (HB) 1763, enacted in 2005, amended the Texas Water Code to require GMAs to determine a "desired future condition" for all aquifers or sub-basins within their boundaries. In establishing this desired future condition, which must be done every five years, GCDs are instructed to consider groundwater availability models and "other data" and promulgate rules that help achieve this adopted condition (HB 1763, 2005). Conceivably, this "other data" could incorporate springflow needs and pumping estimates required to maintain safe yield (Kelly, 2004).

OBSTACLES TO WATER MARKETING BASED ON CURRENT POLICY

The state's use of the rule of capture to address groundwater rights presents the greatest obstacles to developing widespread markets for groundwater as it precludes the internalization of externalities inherent in using a common pool resource like

[10] "Safe yield" refers to the amount of water that can be sustainably withdrawn from an aquifer, balancing recharge with withdrawals to avoid depletion. In aquifers that receive little to no recharge, safe yield may be traded for some type of managed depletion, where conservation and reuse are employed to extend the economically viable life of the aquifer for as long as possible.

groundwater. Even the system of local groundwater conservation districts chosen by the legislature as the preferred method of groundwater management presents its own impediments. More general shortcomings include a lack of available information on potential trades, few legal means for conveying traded water, and the reactionary nature of water policy in the state where little movement is made regarding changes to water regulation until the state is in the throes of a drought. Although none of these policies, alone or in tandem, completely preclude water transfers in Texas (indeed many have occurred over the years), the ability to establish efficient and comprehensive markets for groundwater for aquifers across the state requires that these obstacles be overcome.

Obstacles Presented by the Rule of Capture

From a conservation standpoint, the rule of capture – sometimes called "the law of the biggest pump" – is disastrous. Unlike the concept of reasonable use, which is employed in other states in place of the rule of capture, Texas's doctrine does not mandate that a property owner's pumping adhere to any "reasonable" amount requirements.[11] Any limitations on pumping must be based on wastefulness, and the courts have generally upheld a very narrow definition of what constitutes waste (Easter, et. al., 1998). This fact, combined with the restrictions on selling or leasing water below the surface, means that the rule of capture disincentivizes conservation of water in place, instead prompting landowners to bring as much water to the surface as they can. Because a landowner cannot be protected from the deleterious effects of his neighbors' pumping (such as drawdown, discussed in Chapter One), he is better off reducing to ownership as

---

[11] The Texas Supreme Court considered the application of a "reasonable use" limitation to groundwater pumping in *Sipriano v. Great Spring Waters of America* (1999), and again upheld the rule of capture and its lack of reasonable use limitations. The rule was reaffirmed most recently in *Edwards Aquifer Authority v. Day*, discussed in the "Recent Case Law and Groundwater Regulation" section.

much water as he can, since there is no guarantee enough water will be left in the aquifer for his future needs:

> In short, the rule of capture makes it extremely difficult for landowners to conserve and manage their groundwater assets. Essentially, the only way they can protect their claim is by pumping the water. Unfortunately, the rule has created a race to the pumphouse. Landowners must try to out-pump each other in order to ensure they get their fair share (Landry, 2000, p. 1).

In this paradigm, it seems that groundwater may be less of a common pool resource and more closely resemble an "open access resource" whose use is characterized by "a first-come, first-take, free-for-all that is barren of restrictions" (Easter, et. al., 1998, p. 58).

As discussed in Chapter One, some internalization of the costs to third parties is required in an efficient water market. Whether these third parties be neighboring users, rural communities, future generations, or the species that inhabit aquifer-fed springs, their needs are not being considered in the current rule of capture framework. Until they are, any markets that develop will be unable to achieve optimal efficiency in allocating groundwater.

Obstacles Presented by Current Groundwater Conservation District Policy

The legislation that initially created groundwater conservation districts stipulated that the boundaries of a GCD were to be drawn so that it was "coterminous with a ground water reservoir or subdivision thereof" and in delineating the district, "[a]ll parts of a county or counties, municipal corporations, and other political subdivisions may be included" (Hutchins, 1961, p. 589), suggesting a GCD would conform to the geologic boundaries of the aquifer over which it sat. However, in practice, GCDs have largely been delineated along political boundaries, and most often include only a few counties, leaving much of the aquifer unregulated. In fact, "[t]he majority of groundwater districts are created along county boundaries, rather than following the aquifers' contours… [This method] has been preferred by those seeking to create districts either through voter petition or legislation" (Brock and Sanger, 2003, p. 6). Often, these districts encompass only one county. So many small GCDs created along political, rather than hydrogeologic, boundaries are much less effective than an aquifer-wide entity would be.

In 2001, SB 2 provided for the creation of groundwater management areas (GMAs) by TWDB that were to cover all major and minor aquifers in the state and whose boundaries must ("to the extent feasible") coincide with the geologic boundaries of an aquifer or sub-basin (Kelly, 2004, p. 25). The bill also requires that GCDs within each management area coordinate their groundwater planning efforts, such as sharing resources for data gathering and aquifer modeling, though it does not mandate that the districts adopt joint management goals (ibid). Still, the establishment of GMAs is a step in the right direction in terms of meaningful groundwater conservation and management as it adopts a more integrated approach than the ad hoc activities of individual GCDs. For groundwater marketing efforts, a more holistic understanding of an aquifer's resources can help internalize third party and environmental costs more effectively.

Boundaries also present a problem when one considers that there is no ability to regulate groundwater withdrawals outside GCDs, given the rule of capture. Because the boundaries conform to political, rather than hydrologic, lines, any regulations on pumping that a district sets in order to manage its groundwater supply or achieve its adopted desired future conditions can easily be circumvented by users pumping just outside the district boundaries. While this loophole has implications for conservation and environmental needs, it also hinders the establishment of a viable market by undermining the enforceability needed to give users certainty in their private property rights.

Even within the boundaries of the district, where GCDs have the authority to set pumping limits and register wells, few have exercised this authority in any meaningful way. This may be due in part to the difficulties of regulating your own constituency: groundwater districts can be unsuccessful as “the to-be-regulated groundwater users are little interested in creating a potentially oppressive agency and, if created, the district is politically obligated to its members and is therefore reluctant to pursue substantive change” (Griffin and Boadu, 1992, p. 285). For instance, GCDs in the Texas High Plains area overlying the rapidly dwindling Ogallala Aquifer did not impose pumping limits until 2012, raising an outcry from area farmers (Galbraith, Mar 18, 2012).

Sometimes, even the *establishment* of a groundwater district is difficult to achieve. Often, “fear of increased taxes, regulation, and government control over private property” can be cited as factors in denying the creation of a GCD (Brock and Sanger, 2003, p. 8). The state’s long history of treating groundwater as the “private property” of the landowner and the recent Texas Supreme Court decision affirming a compensable interest in groundwater can only compound the problem as they reflect a strong anti-regulatory ethos when it comes to groundwater extraction.

General Impediments to the Formation of an Efficient Market System

One of the hallmarks of any efficient market, be it in water or in widgets, is the widespread availability of information to both buyers and sellers. Partly a consequence of the limited use of groundwater transactions and partly a consequence of inadequate (or nonexistent) monitoring, a lack of readily available information on buyers, sellers, and the water available for trade currently inhibits the formation of an efficient groundwater market in much of Texas (TWDB, 2003). GCDs could be used to broker a solution to this problem by more uniformly utilizing their powers of registration and permitting, but as previously discussed, this has yet to occur.

From an infrastructure standpoint, few economically viable means of transporting water once it has been sold exist in the state. Because aquifers cannot be used as a transport mechanism (i.e. a seller cannot leave his water within the aquifer to have it extracted by a buyer in another part of the basin), some manmade method of conveyance is required to move water from seller to purchaser. Additional large-scale storage facilities may also be needed. Because such infrastructure represents a significant capital expenditure of the type unlikely to be undertaken by private sellers alone, "[t]here is a general consensus among water marketing experts in Texas that…a combined effort by the State and private enterprise to develop these needed facilities would significantly increase the feasibility of water marketing transactions" statewide (TWDB, 2003, p. 23).

Finally, the nature of Texas water planning itself may prove an obstacle to the implementation of groundwater markets statewide. According to Todd Votteler, Executive Director of Guadalupe-Blanco River Authority, water policy (and the public that influences policy decisions) is too reactive: "we have the opportunity to change our water management practices now and avert real problems later" (personal interview, January 31, 2013), but the danger remains that our attention will be diverted before real change can take place.

But for all the state's past reactionary conduct, the current drought (on track to be the state's new drought of record) has pushed lawmakers to consider the need to change the current regulatory paradigm. At a recent panel of Texas lawmakers, several Republican senators and representatives discussed the need for more conservation and pricing that better reflects the true cost of the resource (Henry, 2013). Although water marketing per se was not mentioned, both conservation and realistic pricing can be achieved through the implementation of market measures with the appropriate institutional oversight. As policymakers recognize the need to find a better regulatory mechanism for groundwater, and as the idea is introduced to the legislature in such reports as Clay Landry's *Free Market Solution to Groundwater Allocation in Texas*, presented to the House Natural Resources Committee in 2000, it may be only a matter of time before Texas more fully embraces a market framework for groundwater allocation.

Chapter Three: Water Marketing in the Edwards Aquifer

The southern Edwards Aquifer region sports the state's only institutionalized groundwater market, overseen by the Edwards Aquifer Authority (EAA). As a result of a judicial mandate to fulfill Endangered Species Act requirements by regulating groundwater use, the traditional rule of capture employed in the rest of Texas was replaced with a permit system overseen by the EAA that allows for water trading. Although the Edwards Aquifer system may not be appropriate for every aquifer in Texas due to the unique characteristics of each aquifer, some exploration of the EAA system may offer guidance on best practices of groundwater marketing as currently employed in Texas.

THE SOUTHERN EDWARDS AQUIFER

Hydrology and Geography

The Edwards (Balcones Fault Zone) Aquifer is one of nine major aquifers in Texas, underlying 13 counties in the south central portion of the state. The aquifer spans 3,874 square miles; 90 percent is within the boundaries of a groundwater conservation district (Figure 5) (George, Mace and Petrossian, 2011).

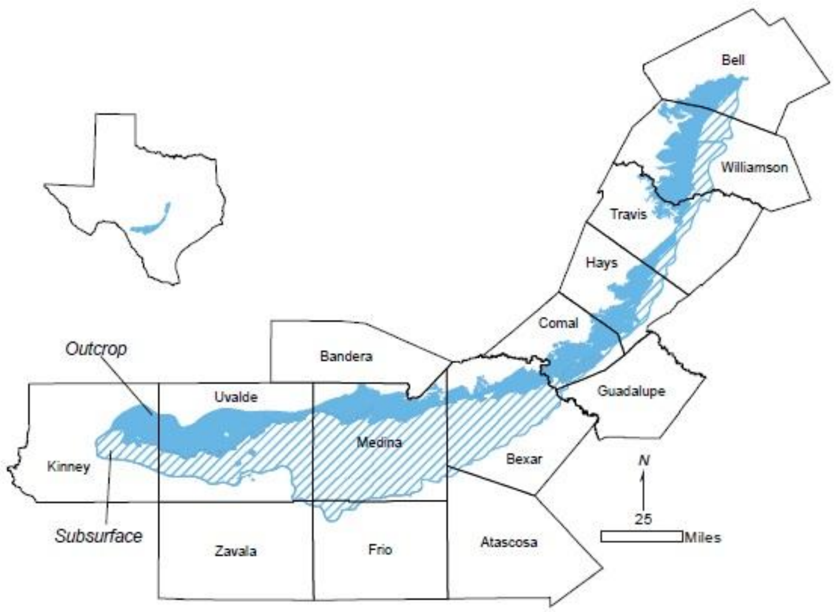


Figure 5: Edwards (Balcones Fault Zone) Aquifer (George, et. al., 2011, p. 27) (Hatched blue denotes subsurface aquifer; filled blue denotes outcrop of aquifer.)

The southern portion of the aquifer falls under the purview of the EAA and runs 180 miles from Kinney County northeast to Hays County. In the ensuing discussion, the southern portion of the Edwards (Balcones Fault Zone) Aquifer will simply be referred to as the Edwards Aquifer.

The aquifer is composed of highly porous limestone, known as karst, resulting in an extremely permeable aquifer and rapid rates of percolation (George, et. al., 2011). This means the effects of recharge – and of depletion or drought – are felt quickly. A review of annual recharge over the period 1934-2001 highlights the extreme variability of recharge to the aquifer, dependent on precipitation and stream flow from overlying river basins. Annual recharge over the period ranged from a low of 43,700 acre feet during the 1956 drought of record to 2,485,700 acre feet in the early 1990s, with the average around 711,000 acre feet (Edwards Aquifer Authority, 2012). In recent years, recharge has been lower than normal; a reflection of the long period of drought conditions (Figure 6).

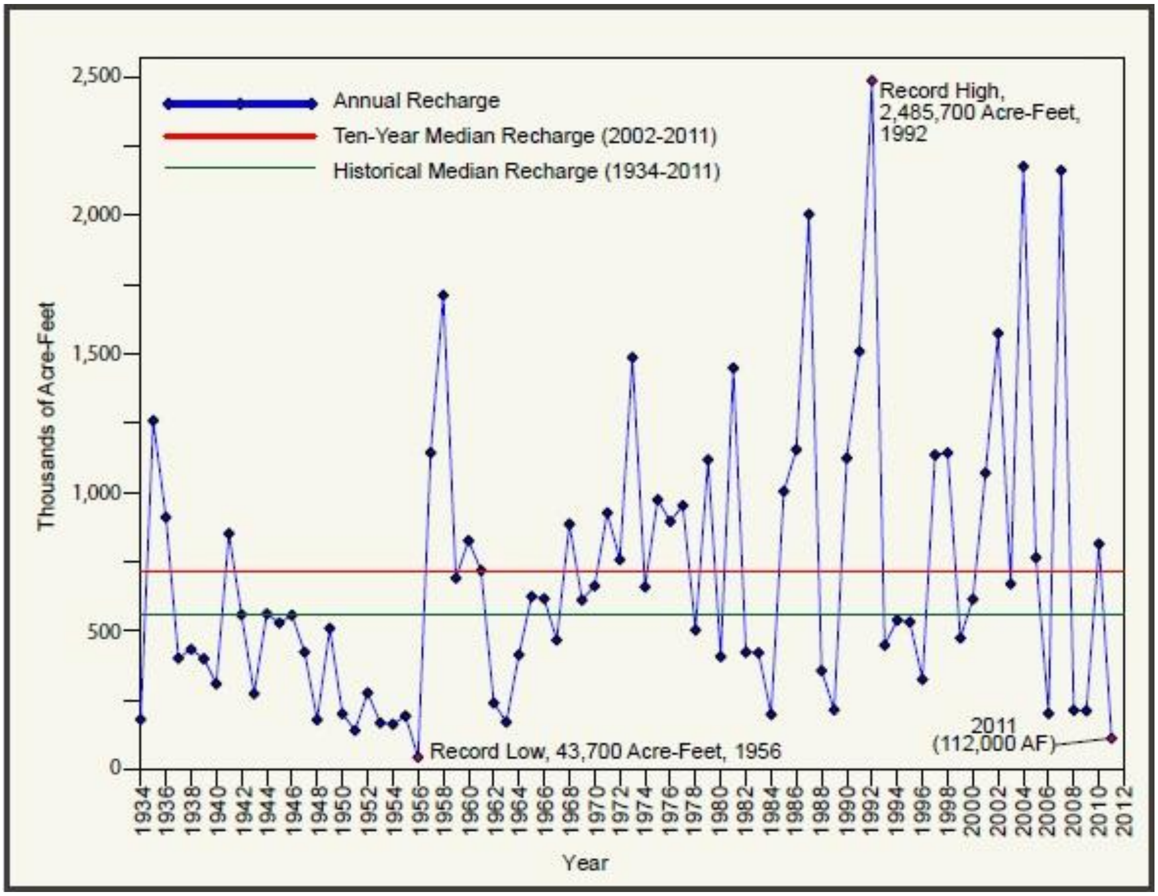


Figure 6: Estimated Annual Recharge and Ten-Year Floating Median Estimated Recharge for the Edwards Aquifer 1934-2011 (Edwards Aquifer Authority, 2012, p. 30)

The aquifer underlies several river basins on its way to the Gulf of Mexico, including the Nueces, San Antonio, and Guadalupe (Anderson and Hill, 1997). It also feeds numerous springs, including Comal Springs and San Marcos Springs, the two largest in the state (George, et. al., 2011).

As the region developed over the twentieth century, increased pumping for municipal and agricultural purposes began to take its toll on the aquifer-fed springs. These springs are home to many unique species, including seven listed on the Fish and Wildlife Service's endangered species list (Griffin, 2011), whose survival depends on maintaining a threshold volume of springflow that may be difficult to sustain in dry periods, given the extensive pumping that is already occurring in the aquifer. Concerns over the fate of these species instigated an intense battle over managing groundwater discharge in the Edwards, which is discussed in further detail in the "Edwards Aquifer Authority" section.

Water Usage

Water use in the Edwards is largely for municipal, agricultural, and recreational purposes, with the city of San Antonio relying almost exclusively on the aquifer (Anderson and Hill, 1997) to meet the demands of its nearly 1.4 million residents. Indeed, the Edwards is known as the first "sole source aquifer" as defined by the EPA in 1977 (US EPA, 2000).

In 2011, municipal use comprised roughly 64 percent of reported aquifer discharge (i.e. pumping), irrigation 31 percent, and industrial uses six percent.[12] Although water use for irrigated agriculture grew rapidly from the mid-twentieth to twenty-first centuries (Votteler, 1998), it is clearly being outpaced by municipal needs. Indeed, municipal demand in Planning Region L (encompassing San Antonio and most of the Edwards Aquifer) is projected to grow rapidly into 2060 to over 600,000 acre feet, while irrigation and industrial needs remain about or below 400,000 acre feet (TWDB, 2012). Because of San Antonio's historic reliance on the Edwards, the city has not extensively developed the physical infrastructure needed to bring in additional water supplies

[12] Sum exceeds 100% due to rounding. Total reported pumping in 2011 amounted to 408,628 acre feet. Unreported pumping was estimated to be an additional 19,025 acre feet, 72% of which was attributed to domestic or livestock uses, which are exempt from reporting requirements (Edwards Aquifer Authority, 2012).

(Votteler, 1998). Therefore, in the event of a drought, unmet demand could total 436,751 acre feet, 68 percent of which represents municipal demand (TWDB, 2012).[13]

THE EDWARDS AQUIFER AUTHORITY

Springflows and Sierra Club v. Babbitt

The Edwards Aquifer feeds five large springs: Leona, San Antonio, San Pedro, Comal, and San Marcos (Boadu, McCarl and Gillig, 2007). The Comal and San Marcos Springs are among the largest in the state and provide habitat for a range of unique species not found outside these Central Texas springs. The effects of pumping on the springs, especially during drought conditions, can be catastrophic:

> [During the drought of record in the 1950s,] Comal Springs ceased to flow for 144 days in 1956. Although a total of 321,000 acre feet of water was [sic] pumped from the aquifer that year, groundwater modeling indicates that in the absence of aquifer pumping, Comal Springs would have continued to discharge at about 300 [cubic feet per second] throughout the summer of 1956" (Griffin, 2011, p. 84).

As pumping has increased, the volume of water available for these springs has diminished, causing springflow to fall to levels that threaten the survival of the springs' unique species. In recent years, drought conditions have pushed springflow levels closer to – and often below – critical levels (Figures 7 and 8).

[13] At the time the 2012 water plan was published, Region L had already estimated that a drought would result in a shortage of 175,235 acre-feet *in 2010*. 55 percent of that amount represented municipal demand (TWDB, 2012).

Figure 7: Comal Springs Water Levels, January 2010 – March 2013 (Edwards Aquifer Authority)

Figure 8: San Marcos Springs Water Levels, January 2010 – March 2013 (Edwards Aquifer Authority)

These considerations prompted the Sierra Club (along with other plaintiffs including the Guadalupe Blanco River Authority) to file a lawsuit against the US Fish and Wildlife Service in 1991, alleging that the bureau (under the purview of Secretary of the Interior Bruce Babbitt) violated the Endangered Species Act by failing to maintain springflow levels, resulting in the takings of several endangered species that live within the springs (Griffin, 2011). The plaintiffs requested that the court enjoin the FWS to maintain springflow levels by restricting pumping under certain conditions and to implement recovery plans for affected species. In February 1993, District court judge Lucius Bunton found in favor of the plaintiffs, requiring FWS to determine the minimum springflow required to sustain the endangered and threatened species, and required the State of Texas to develop a plan to protect minimum springflows and aquifer levels by May 31, 1993. If the State failed to adopt such a plan, Judge Bunton maintained that Sierra Club could return to court and sue to put the Edwards Aquifer under the federal control of the FWS (Votteler, 1998).

Edwards Aquifer Authority Enabling Act

On May 30, 1993 – the day before the judicially mandated deadline – the legislature passed SB 1477, establishing a new regulatory authority to oversee pumping in the Edwards Aquifer. The new conservation and reclamation district, called the Edwards Aquifer Authority (EAA), was given "all of the powers, rights, and privileges necessary to manage, conserve, preserve, and protect the aquifer and to increase the recharge of, and prevent the waste or pollution of water in, the aquifer" (Edwards Aquifer Authority Enabling Act, §1.08). Such powers include overseeing and enforcing the permitting, metering, and reporting of wells and closing abandoned, wasteful or dangerous wells (§1.11). The EAA may exercise these powers over eight counties, encompassing all of Bexar, Medina, and Uvalde, and portions of Atascosa, Comal, Caldwell, Hays, and Guadalupe (Edwards Aquifer Authority, 2010). Thus, the Edwards Aquifer Enabling Act effectively replaced the traditional rule of capture for a regulated permit system in each of these jurisdictions.

Under the act, no water can be withdrawn from the aquifer (barring a few exceptions, such as for exempt wells of less than 25,000 gallons per day used for domestic or livestock purposes) without a permit granted by the EAA (§1.15). Further, no withdrawals are to be made from wells drilled after June 1, 1993, except for replacement, test, or exempt wells, or "to the extent that the authority approves an amendment to an initial regular permit to authorize a change in the point of withdrawal under that permit" (§1.14(8)(e)). This provision affords an opportunity for a robust water market in the Edwards Aquifer, enabling the EAA to grant and oversee water transfers from one user to another.

To meet its burden of conserving water for the endangered species in the Comal and San Marcos springs, the EAA was also required to set a pumping cap of 400,000 acre feet per year by January 1, 2008 (Griffin, 2011). Though the EAA can purchase and retire water rights to meet this goal (Votteler, 2000), the cap was raised by the legislature in 2007 to 572,000 acre feet per year, or "the sum of all regular permits issued or for which an application was filed and issuance was pending action by the authority as of January 1, 2005" (Enabling Act, §1.14(c)), most likely as a result of political pressure.

The 400,000 acre feet figure was not set arbitrarily; on the contrary, the threshold was calculated in the 1968 state water plan to be the maximum level of pumping that could occur in the Edwards Aquifer to ensure safe yield. However, even with a 400,000 acre foot-cap on pumping, modeling indicated that Comal and San Marcos Springs would not always be able to flow continuously (Griffin, 2011). When the cap was raised in

2007, TWDB modeling showed that even with drought period reductions to 340,000 acre feet, allowing such a high level of pumping during typical years would deplete the aquifer enough to result in the elimination of Comal Springs's flow for 25 to 30 months during a drought of record (ibid). The drying up of Comal Springs for an entire year would clearly result in a taking of the endangered and threatened species covered under the Endangered Species Act, which could prompt additional lawsuits and potential federal action.

Edwards Aquifer Permitting System

Pursuant to the enabling act's mandate that the EAA permit and regulate withdrawals from the aquifer, the authority began adjudicating water rights in 1996, after the flurry of constitutional challenges that greeted its inception were resolved.[14] The adjudication was based on historical use over the period 1972-1993 (EAA Rules, §702.1 (90)). To obtain a permit in the initial adjudication process, a water user had to provide proof of beneficial use over the historical period. The EAA would then issue an initial regular permit to the pre-existing well owner. Initial historical use claims totaled 852,800 acre feet (nearly double the initial statutory pumping cap of 450,000 acre feet) (Votteler, 1998). While the pumping cap was raised by the legislature in 2007, as discussed in the previous section, the EAA instituted a pro rata reduction approach to bring these initial applications in line with the statutory pumping requirements (EAA Rules, §711 (g)). In addition to setting permits based on maximum historical use, the statute also provides for

[14] These challenges include a US Department of Justice allegation that the enabling act's replacement of the former Edwards Aquifer Underground Water District's elected board with the EAA's appointed board violated the Voting Rights Act, rendering the act unconstitutional. A revision to the act passed in 1995 remedied the issue and put the establishment of the EAA back on track. It was soon derailed, however, by allegations of unconstitutionality brought by the Medina County and Uvalde County Underground Water Districts that were upheld by a district court in October 1995. The district court decision was overturned by the Texas Supreme Court eight months later and the EAA began the permitting process. For a more detailed description of these events, see Todd Votteler, *The Little Fish that Roared* (1998) p. 19, 24-27.

minimum amounts to be met for irrigators and users who operated wells for at least three years (Velma Danielson, personal interview, January 25, 2013).[15]

According to a past EAA general manager, the EAA often issued several different amounts per permit. A period of time was allowed for applicants to contest these amounts (either their own permits or the permits of others) and some applicants denied the authority's numbers outright, or proposed different amounts. Such contested cases meant that the adjudication process was a lengthy one, taking roughly seven years to complete (ibid).

In addition to initial regular permits, the EAA is authorized to issue three other permit types: term permits, emergency permits, and recharge recovery permits. Each of these permit types may be applied to agricultural, municipal, or industrial uses, but a permit cannot be used to satisfy multiple uses simultaneously (EAA Rules, §711.90).

While the initial regular permits discussed above have no term limits, term permits can be granted for a period of up to ten years. Term permits may be suspended when indicator wells or springflow levels fall below certain trigger levels and the proposed withdrawals must not unreasonably negatively impact other extant permit holders in the Edwards Aquifer. Term permits are only granted to property owners in the EAA region that do not have access to a municipal system (EAA Rules, §711.102).

Emergency permits, which are non-interruptible regardless of drought conditions, may be granted for a period of up to thirty days (but can be renewed if necessary) to prevent "loss of live or severe, imminent threats to the public health or safety" (EAA

[15] For irrigators, this minimum amounts to two acre feet per acre irrigated in any calendar year during the historical period (§702.1 (103)). For multi-year well operators, the historical average minimum is calculated and informs the permit amount (§711.172 (f)(3)). Because the EAA's permitting rules awarded permit applicants who qualified for both minimums the higher of the two, (§711.172 (f)(6)) the historical average minimum was utilized mostly by municipal and industrial users (Danielson, personal interview, January 25, 2013).

Rules, §711.104). Recharge recovery permits are required for any aquifer storage and recovery project within the EAA's boundaries (§711.243).

While each of these alternative forms of permits (term, emergency, and recharge recovery) address important needs of water users in the aquifer and contribute to the overall enforcement of the regulatory system, only initial regular permits may be transferred. Initial regular permits may be transferred separately from ownership of the land on which the well is located, except in the case of base irrigation water, which is appurtenant to the land on which it has historically been used (§711.324 (b,d)). To grant the transfer of all or part of a water right in perpetuity or for a finite period, the EAA general manager must ascertain that the purpose of use is a beneficial one and that the place of use is within the EAA's boundaries (§711.328 (10,11)). What constitutes beneficial use has been widely construed and so is unlikely to prevent a transfer, but the restriction on place of use effectively eliminates the possibility of interbasin transfers of water from the Edwards Aquifer.

Permits are not required for exempt wells, or those that produce 25,000 gallons or less per day and are used solely for domestic or livestock purposes (§711.20). Operators of exempt wells are only required to register the well with the EAA; they are not required to quantify their historical use or obtain a withdrawal permit. Exempt well owners may only use the water they withdraw on the land on which the well is located or on an adjoining tract they also own or lease (§711.30). Ownership of exempt wells may be transferred simply by filing a new registration (§711.326 (d)), but the restrictions on place of use and the amount that can be withdrawn mean that transfers of water from exempt wells do not constitute the most efficient type of water trades available in a market system.

Although exempt wells are required to be registered with the EAA, not all well owners have done so (Brock Curry, personal interview, February 20, 2013). This uncertainty regarding the number of exempt wells in operation makes it difficult for the EAA to effectively monitor and regulate the total amount of water being withdrawn from the aquifer: if thousands of exempt wells are all pumping their allotted 25,000 gallons per day (gpd), this can contribute significantly to overdraft, even in spite of the authority's best efforts to regulate permit holders. Understanding this shortcoming, the EAA is currently seeking to find and register all exempt and non-exempt wells within its jurisdiction on a county-by-county basis. While the EAA is fairly certain that it has already identified and permitted the majority of non-exempt wells, the number of exempt wells left to be registered is likely much larger. A field survey of Hays County has been recently completed and a survey of Comal County began in February 2013 (ibid). Based on the Hays County findings, the EAA estimates there may be 13,000 exempt wells within the authority's jurisdiction. Another estimate is derived from assuming there are 25,000 total wells within the EAA boundaries, 70 percent of which are exempt, totaling 17,500 exempt wells. Thus the EAA's current estimate of exempt wells ranges from 13,000 to 17,500 wells (Ron Vaughn, personal communication, February 21, 2013). Even if these well users are pumping only half their allotted 25,000 gpd, their usage still amounts to between roughly 182,000 and 245,000 acre feet per year. While it is unlikely that every exempt well pumps even a quarter of their daily allotment, this extreme example illustrates just how detrimental a large (and unknown) number of exempt wells can be for monitoring and managing aquifer levels. From a market efficiency standpoint, the waiving of exempt well users' permitting requirements could present enforceability and encroachment issues if the volume of water they are allowed to pump is not capped at a level sufficiently low enough to prevent negative impacts to neighboring well users.

Water Market Activity within EAA Boundaries[16]

Water rights transfers in the Edwards Aquifer region began in 1997, though digitized recordkeeping dates back only to 2005 (Curry, personal interview, February 20, 2013). The EAA estimates that on average, 500 to 600 transfers take place per year, with the majority of those transfers consisting of leases.

From the period January 2005 to February 2013, 3,709 water rights transfers have taken place in the EAA's jurisdiction. 40 percent of these transfers were permanent sales, with the remaining transfers comprised of leases ranging in terms of a few days to over thirty years. 13 percent of these transfers were part of property transactions where both the land and the water rights were sold.

The majority of transferors were agricultural interests selling irrigation rights (84 percent). Municipal and industrial transferors accounted for only 8 percent each. The buyers for these water transfers were also largely agricultural interests, with 72 percent of transferees' permitted uses recorded as irrigation. Municipalities comprised the remainder of the transferees, accounting for 28 percent of the water trades.

From the numbers, it is clear that irrigation users still account for much of the water market activity in the Edwards Aquifer. Transfers from agricultural to municipal uses are occurring, but transfers between agricultural users themselves are still a much higher proportion of overall transfers. More broadly, it is clear that there is a demand for trading water rights apart from land, with only 13 percent of the trades occurring as part of land-based transactions.

---

[16] Calculations in this section based on database of water rights transfers spanning 1/1/2005 to 2/19/2013, courtesy of the Edwards Aquifer Authority, February 2013.

Dealing with Drought

As part of its enabling legislation, the Edwards Aquifer Authority is required to develop a Critical Period Management Plan (CPMP) to manage withdrawals during drought periods (§1.26). The current CPMP reduces withdrawals by a set percentage at each of four stages, as defined by certain "trigger levels" at two indicator wells and Comal and San Marcos Springs (Figure 9).

EDWARDS AQUIFER AUTHORITY

Critical Period Triggers, Stages, and Withdrawal Reductions

*The following Critical Period triggers and percent reductions apply to all Municipal, Industrial and Irrigation users.

SAN ANTONIO POOL **

TRIGGER (based on 10-day average)	CRITICAL PERIOD STAGE I	CRITICAL PERIOD STAGE II	CRITICAL PERIOD STAGE III	CRITICAL PERIOD STAGE IV
Index Well J-17 Level (MSL)	<660	<650	<640	<630
San Marcos Springs Flow (CFS)	<96	<80	N/A	N/A
Comal Springs Flow (CFS)	<225	<200	<150	<100
Withdrawal Reduction	20%	30%	35%	40%

UVALDE POOL ***

TRIGGER (based on 10-day average)	CRITICAL PERIOD STAGE I	CRITICAL PERIOD STAGE II	CRITICAL PERIOD STAGE III	CRITICAL PERIOD STAGE IV
Index Well J-27 Level (MSL)	N/A	<850	<845	<842
San Marcos Springs Flow (CFS)	N/A	N/A	N/A	N/A
Comal Springs Flow (CFS)	N/A	N/A	N/A	N/A
Withdrawal Reduction	N/A	5%	20%	35%

Definitions: (MSL) Mean Sea Level (CFS) Cubic Feet Per Second

*Applies to any user who is authorized to withdraw more than 3 acre-feet.

**San Antonio Pool--Critical Period is declared when the 10-day average of the rate of springflow at either the Comal or San Marcos springs, or aquifer level readings at the J-17 Index Well in Bexar County drop below the Stage I trigger level. Likewise, a more restrictive stage of Critical Period is activated by any one of these triggers. However, the declaration of a less restrictive stage of Critical Period requires the 10-day averages of all three trigger levels to be above the activation thresholds of the particular stage in effect at the time.

***The Uvalde Pool enters Critical Period at Stage II based on the 10-day average of aquifer level readings at the J-27 Index Well in Uvalde County.

Figure 9: EAA Critical Period Management Plan Trigger Levels and Withdrawal Reductions (edwardsaquiferauthority.org)

Because the EAA took a correlative approach to adjudicating water rights, as opposed to the seniority-based appropriative rights approach used for surface water rights, critical period reductions apply equally to all permit holders, regardless of how long they have been pumping. Although the EAA initially sought to restrict certain types of uses when conditions threatened to lower springflows to critical levels (Votteler, 1998), the current framework applies reductions across the board, regardless of use.

In addition to the CPMP, the EAA was also required to produce a recovery implementation program (RIP) for species impacted by low springflow levels (Griffin, 2011). The EAA, in partnership with Texas A&M University, developed a Habitat Conservation Plan (HCP) to meet this burden. The resulting plan, released in late 2011, seeks to minimize and mitigate the negative impacts that continued pumping will have on the springs' endangered species through a variety of measures, including regional conservation and voluntary irrigation suspension programs (RECON Environmental, 2012).

The HCP was also used to acquire an Incidental Take Permit (ITP) under Section 10(a) of the Endangered Species Act (Griffin, 2011). The ITP will allow water users in the EAA's jurisdiction to continue to pump water from the aquifer even as spring discharge rates drop to levels that may constitute a take of one of the 11 endangered species in the springs. Under the ITP, pumpers may withdraw water until jeopardy springflow levels are reached. ITPs are required where non-federal actions will result in the take of endangered species, but the minimization and mitigation measures contained within the HCP are designed to prevent these levels from being reached and protect the endangered species within the springs (ibid).

The EAA's Habitat Conservation Plan represents an important consideration and internalization of the needs of the environment in making water allocation decisions.

Because the critical period trigger levels are based on the levels that may result in a take of the endangered or threatened species within the springs, the needs of these species directly inform the pumping limits for water users, thereby internalizing the negative externalities that would otherwise impact the environment.

Strengths and Weaknesses

The EAA system has created an effective market for groundwater in the Edwards Aquifer and is taking steps to incorporate environmental needs into permitting decisions. However, this incorporation is limited in its application, as shown by the legislature's raising of the permitting limit and the recent adoption of an Endangered Species Act Incidental Take Permit.

Recognizing the importance of exempt wells to overall planning and permitting activities, the EAA is currently working to register all wells in its eight-county region. Once this initiative is complete, the authority will have a more complete knowledge of the number of wells and amount of water being withdrawn throughout the aquifer, allowing it to better manage the resource in the interests of both pumpers and endangered species alike.

The authority's adoption of a pro rata system of pumping reductions during critical periods also has beneficial implications for groundwater management. As will be discussed in Chapter Five, by reducing all water rights holders' allotments across the board, the EAA reduces the possibility that junior rights holders will race to pump as much water as they can before their allotments are suspended in times of severe drought. Additionally, this across the board reduction possibility facilitates water marketing by making all water rights equally attractive: potential buyers will be more willing to purchase junior water rights if they have the security of knowing their rights won't be completely suspended during drought periods.

Additionally, the EAA has acknowledged that pumping from the Edwards Aquifer can affect nearby surface water bodies and other aquifers that lay close to the Edwards under the surface. While this recognition has not yet influenced policy at the EAA, it is informing the authority's research approach, and may affect groundwater management decisions in the future (South Central Texas Water Advisory Committee, 2010).

The Habitat Conservation Plan also represents a positive step toward meaningfully incorporating environmental needs into the groundwater marketing and management process. While the EAA's situation is unique in that it was created following a federal mandate to protect endangered species, an HCP-type analysis that quantified the needs of species within aquifer-supported habitats would be a beneficial addition to any groundwater market in Texas.

However, the Incidental Take Permit that was granted by the US Fish and Wildlife Service in February 2013 diminishes the significance of the HCP in protecting endangered species by allowing pumping to continue up to and beyond a taking of an endangered species. While there may be legitimate social and economic benefits associated with this ITP, the fact remains that by allowing pumping to continue beyond an unsafe level of springflow, the ITP fails to fully incorporate the environmental externalities of groundwater withdrawal into the pumping regime. This tendency to stop short of complete internalization of environmental impact is also reflected in the legislature's amendments to the permitting limit in 2007 that raised the amount available to be permitted far beyond the level required to maintain continuous springflow. Thus, while the EAA provides a remarkable example of adjudication of an aquifer and the subsequent forging of a viable water rights market, it fails to fully account for the environmental impacts it was created to address.

The EAA represents only one application of a marketing system to groundwater resources. This report now turns to case studies from other western states to provide a broader view of the possible forms water markets may take.

Chapter Four: Water Marketing Frameworks in Other States

Given the EAA's beginnings in an Endangered Species Act lawsuit and federal mandate to regulate groundwater pumping, the EAA framework may be difficult to implement in every major aquifer across the state of Texas, where these characteristics are lacking. Therefore, other western states' methods of managing groundwater withdrawals and trades can provide a better picture of statewide mechanisms that could be employed in Texas. To this end, this chapter explores water law and marketing systems in three western states: Arizona, New Mexico, and California. Arizona and New Mexico are chosen for their extensive groundwater management regulatory frameworks and corresponding active water markets in groundwater, providing a direct comparison to Texas's groundwater system. California is discussed because, like Texas, the state experiences significant hydrological diversity, ranging from very dry to very wet conditions across the state. California is also the only state to employ a conjunctive use approach to managing surface water and groundwater in tandem, providing an interesting counterpoint to the other states considered.

State	Texas	Arizona	New Mexico	California
Rule of Law	Rule of Capture	"American" rule of reasonable use	Prior Appropriation	Prior Appropriation and Correlative Rights
Permitting Entity	Edwards Aquifer Authority (only for Edwards Aquifer)	Department of Water Resources	Office of the State Engineer	State Water Resources Control Board, local groundwater districts
Number of Transfers	336	217	138	638
Volume of Transfers in acre feet	2.9 million	8.4 million	678,000	13.3 million

Table 1: Comparison of the Selected Case Studies

ARIZONA

Water Law

Just as Texas law manages groundwater and surface water separately, so too does Arizona's, applying the prior appropriation doctrine to surface water and historically leaving adjudication of groundwater largely up to common law (Schaeffer, 2009). In the early twentieth century, Arizona began to apply the reasonable use doctrine to the management of percolating groundwater;[17] this doctrine views groundwater as property of the overlying landowner and subject only to loosely defined restrictions of "reasonable use" (Smith, 1984). As with Texas's rule of capture doctrine, the pumper is protected from liability if his pumping negatively impacts his neighbors' ability to pump (provided

[17] As in Texas, Arizona distinguishes between percolating groundwater and underground water that is confined to clearly defined channels or streams, with a presumption toward percolating groundwater (Smith, 1984).

his use is "reasonable"). The lack of a rigid interpretation of what constitutes reasonable use in Arizona led to significant overdraft of groundwater resources even in the early decades of the twentieth century (Evans, 2010).

This rapid depletion led the legislature to consider placing restrictions on groundwater use in the 1940s, culminating in the passage of the Ground Water Act of 1948. The act allowed the state land commissioner to designate critical groundwater areas in basins that had insufficient groundwater supplies to provide irrigation water for the lands currently under cultivation (Peacock, 1994). However, the act proved ineffective at ameliorating the overdraft problem as it did not apply to municipal or industrial uses and did not mandate pumping reductions in critical basin areas, but merely prohibited *new* lands from being irrigated, maintaining the overdraft at current levels (Smith, 1984).

Groundwater Management Act of 1980

In the late 1970s, the state's groundwater troubles threatened to derail completion of its largest surface water project, the Central Arizona Project, as the Secretary of the Interior threatened to withdraw construction funding for the project if the state did not implement a more effective method of groundwater management (Avery, et. al., 2007). With this direct mandate hanging over their heads, the Arizona legislature passed the Groundwater Management Act (GMA) in 1980.

The law cites the need to control groundwater overdraft to avert statewide economic crisis and applies the concept of "safe yield" to aquifers that are particularly threatened (Peacock, 1994, p. 16). The act defines safe yield as a "long-term balance between the annual amount of groundwater withdrawn [in a designated basin] and the annual amount of natural and artificial recharge [in that basin]" (Arizona Rev. Statutes, §45-561(12)), that is, zero overdraft. Under the act, safe yield must be achieved by 2025.

Safe yield is applied to Active Management Areas (AMAs) where groundwater overdraft is most severe (Folk-Williams, 1985).[18] The GMA originally designated four AMAs: Phoenix, Tucson, Pinal, and Prescott, which at the time comprised over 80 percent of the state's population and accounted for 69 percent of its overdraft[19] (Smith, 1984). The act also provided for the creation of additional AMAs over time, either at the discretion of the director of the Department of Water Resources to protect water quality or supply or avoid subsidence, or at the behest of local voters who want to create an AMA in their area (ibid). Since the passage of the act, one additional AMA has been formed: the Santa Cruz AMA was created from the Tucson AMA in 1994 (ADWR, 2013).

[18] The act also contains provisions for general regulations that apply statewide and for Irrigation Non-Expansion Areas (INAs), usually rural areas where overdraft is less severe.
[19] While these areas still contain 80 percent of Arizona's population, they now account for 70 percent of total overdraft (ADWR, 2013).

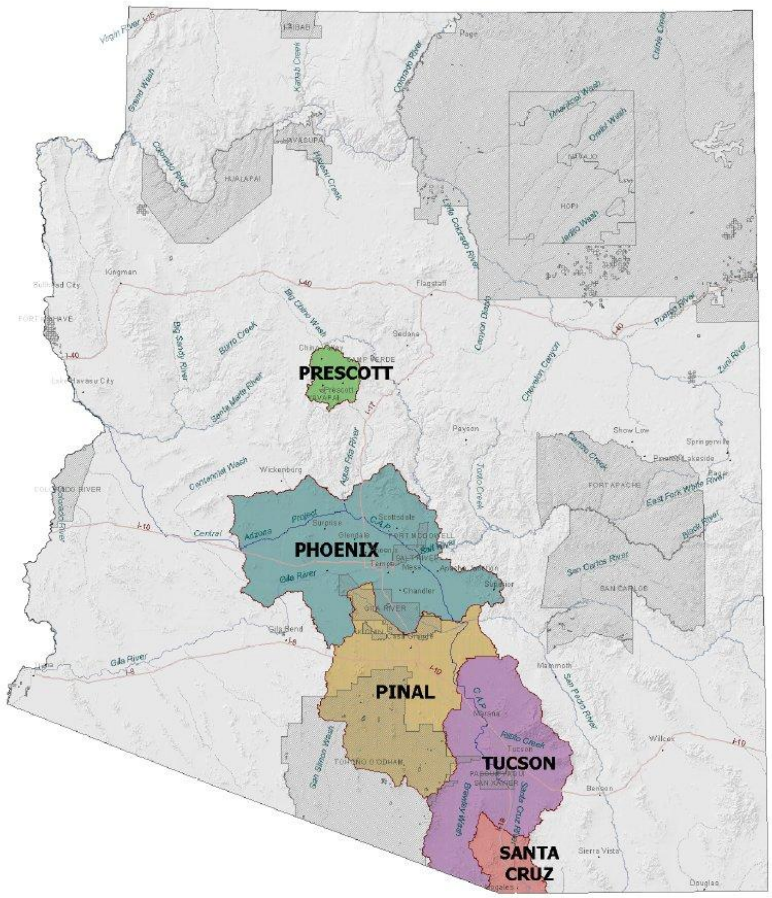


Figure 10: Arizona Active Management Areas (Arizona Dept of Water Resources)

To implement the GMA, the Department of Water Resources (DWR) was created and given broad jurisdiction over management of groundwater and surface water, flood control, dams, the Central Arizona Project, and limited control over water quality (Peacock, 1994). The DWR is responsible for quantifying and permitting groundwater rights and promulgating and enforcing a series of increasingly stringent AMA management plans.

Permitting Groundwater Withdrawals

Within the AMAs, all groundwater rights must be quantified and permitted. The largest group of permits consists of grandfathered rights for pre-existing users, the result of a political compromise that enabled the state's most comprehensive groundwater regulation to be passed (Avery, et. al., 2007). Within this category, there are three types of grandfathered rights applied to different uses and with different restrictions.[20] Irrigation grandfathered rights are attached to two or more acres of land that were irrigated during the period 1975 to 1980 and were cultivated for sale or for human or livestock consumption. These rights are quantified based on the water use per acre (water duty), the number of grandfathered acres, and the maximum number of acres irrigated during any year in the historical period (water duty acres). Irrigation grandfathered rights may be switched to non-irrigation purposes, but non-irrigation rights may not be converted into irrigation rights. These rights are appurtenant to the land.

Type I non-irrigation grandfathered rights are also appurtenant to the land and are associated with lands permanently retired from agricultural production. Type I rights established with the passage of the GMA are entitled to three acre feet per acre; Type I rights converted from irrigation grandfathered rights after 1980 are allowed three acre feet per acre or the maximum amount of water per acre allowed under the irrigation right, whichever is less. Water obtained from a Type I right can be transported outside of the AMA for use elsewhere, provided the water is used for a non-agricultural purpose.

The final type of grandfathered rights, Type II non-irrigation grandfathered rights, must be used for non-irrigation purposes and are based on the maximum amount of water pumped during the historical period 1975 to 1980. After an AMA has been designated, no

---

[20] The following descriptions of the three types of grandfathered rights draw from Saliba, et al. *Water Marketing in the Southwest* (1987) p. 5-6 and ADWR (2013) *Overview of the Groundwater Management Code.*

new Type II rights will be granted. These rights are similar to those established within the EAA's jurisdiction as they can be divorced from the land and traded separately. However, although portions of the right may be leased, Type II rights can only be sold in their entirety. Point of withdrawal may be altered for these rights as well, as long as the new well is still located within the same AMA.

Prospective water users in AMAs may purchase or lease grandfathered rights, but the purpose of use is not easily changed, with the exception of converting an irrigation right to a non-irrigation right (Saliba, 1987).

In addition to grandfathered rights, users can obtain water through service area rights or withdrawal permits. Service area rights generally apply to municipal water providers (either public or private) and irrigation districts. While service area rights are not quantified, mandatory reductions in per capita water use as required by the GMA-mandated management plans are assumed to help control service area withdrawals (ibid).

Finally, withdrawal permits may be obtained for new non-irrigation uses if the applicant is unable to obtain water from a service area or by purchasing grandfathered rights. These permits may be issued for a variety of uses, including industrial, power generation, and mineral extraction. These permits specify the amount of water that can be withdrawn and are issued for a temporary duration, but the time horizons are often fifty years with the option for renewal (Ariz. Water Code, Title 45 Ch.2 Art. 7).

As in the Edwards Aquifer, certain withdrawals may be exempted from permitting requirements. Wells that cannot pump more than 35 gallons per minute (or 50,400 gpd, more than double the EAA's limit of 25,000 gpd capacity for exempt wells) and are used for non-commercial irrigation purposes are not required to obtain a withdrawal permit or grandfathered right. However, users of these wells are required to register them with the Department of Water Resources (Ariz. Water Code, 45-454).

Once an AMA has been designated, no new lands may be irrigated with groundwater. Only those acres that can be shown to have been irrigated with groundwater during the historical period (1975-1980) can use groundwater for irrigation (ADWR, 2013). In addition, with each subsequent management plan, the amounts of water provided by these grandfathered irrigation rights are steadily lessened through DWR-issued decreases in the water duty. Farmers can choose to withdraw less than their allotted amount in one growing season and withdraw the remainder (in addition to that year's allowance) in the next year. Conversely, a farmer may choose to withdraw more than his allotted amount in one year and less the next year to make up for the previous overdraft (Smith, 1984).

In addition to permitting groundwater rights, the DWR is also responsible for metering wells, overseeing the annual reporting of well users, and may investigate and prosecute violations of permitting requirements (Peacock, 1994), providing the institutional oversight and enforcement necessary to ensure that property rights in water are protected, as is required in an efficient market system.

AMA Management Plans

Under the GMA, the DWR is required to promulgate and implement a series of management plans every ten years that help the AMAs reach safe yield by 2025 (Ariz. Water Code, 45-563). The management plans span the periods 1980-1990, 1990-2000, 2000-2010, 2010-2020, and 2020-2025 and contain increasingly stricter conservation requirements for agricultural, municipal, and industrial users within the designated AMAs (ADWR, 2013).

As part of the DWR's role in achieving safe yield, the agency is empowered to purchase and retire irrigated land and extinguish the appurtenant water rights after 2006 if the AMAs have not made satisfactory progress toward their goals (Peacock, 1994). While the AMAs have not yet achieved safe yield, there is some indication/consensus/concern that the funds set aside for purchasing and retiring agricultural lands and their associated water rights are inadequate, preventing DWR from aggressively using this option to help manage groundwater demand (Maguire, 2007).

Water Market Activity

Prior to the passage of the GMA, relatively few water transfers occurred in Arizona (Woodard, 1989).[21] The enactment of the GMA allowed the physical transportation of water to occur from one basin or sub-basin to another without liability, which had been virtually impossible under restrictions previously imposed through common law (Schaffer, 2009). Because irrigation and Type I non-irrigation grandfathered rights are appurtenant to the land under the GMA, many municipalities that were prohibited from pumping without a permit in newly designated AMAs began buying up rural land outside the AMA boundaries in order to pump and transport the water underneath (ibid). This practice, known as "water farming," ran rampant during the late 1980s as cities rushed to buy up water rights to meet their future demands, generating intense opposition from rural communities afraid of losing their water to large cities. Policies like the Groundwater Transportation Act of 1991 and the completion of the Central Arizona Project helped lessen the practice as more restrictions were placed on water farming and urban areas turned their attentions to alternative sources (Colby, McGinnis, and Rait, 1989).

---

[21] For a brief discussion of the most notable water transfers prior to the GMA, see Schaffer. (2009). "Davis v. Agua Sierra Resources," *Arizona Journal of Environmental Law and Policy*, 1(1), 32-33.

Over the period 1988-2009, 217 transfers occurred in Arizona, 32 percent of which were leases. In terms of volume traded, leases counted for an overwhelming 92 percent of the 8.4 million acre feet traded (WGA, 2012).[22]

Strengths and Weaknesses

The GMA allows for water users within AMAs to sell or lease certain water rights separately from land, enabling a market in groundwater to exist, much as the EAA's enabling act did for the Edwards Aquifer. The system can be applied statewide, however, providing a macro-level framework that could be more easily applied to other aquifers than taking the ad hoc approach used in establishing the EAA. Several characteristics of the Arizona groundwater regulatory framework help incentivize an efficient allocation of groundwater that still considers environmental needs and could be advantageously applied Texas. However, the Arizona approach does possess certain shortcomings that should be addressed if applying a part of the Arizona framework to another state.

The GMA's goal of safe yield brings the concept of sustainability into the heart of the groundwater management framework. Any market system that evolves from a regulatory regime with safe yield as its ultimate goal will therefore automatically take environmental and third party needs into account by ensuring that the water table is maintained, or in aquifers with little recharge, that the water table does not decline too rapidly.

Another strength of the Arizona system is its consolidation of regulatory oversight in a central agency, the DWR. The agency is empowered to manage groundwater use statewide, overseeing permitting, enforcement, and trades in every AMA. And although

[22] WGA estimates are based on a dataset from *The Water Strategist* journal and represent both surface and groundwater trades over the period. The dataset is not comprehensive and likely underestimates the volume and numbers of trades (WGA, 2013, p. 14).

groundwater and surface water are managed separately in Arizona, the DWR does have jurisdiction over both, enabling the same decision makers to take surface water and groundwater issues into account when making decisions. If conjunctive use were to be adopted as the preferred water management approach, it would be easier to effectively institute the change in Arizona than in Texas, where surface water and groundwater are still managed by different agencies.

Unlike the groundwater conservation districts employed in Texas's statewide water planning process, AMAs tend to be defined by the boundaries of aquifers and sub-basins, rather than jurisdictional boundaries (ADWR, 2013). As discussed in Chapter Two, delineating groundwater management boundaries along hydrogeologic lines ensures that the groundwater resource is managed effectively by bringing all users who pump from the aquifer into the same permitting system, preventing some pumpers from benefitting from lax or nonexistent regulation at the expense of their permitted neighbors.

However, as is the case outside the Edwards Aquifer, the areas outside AMAs are largely unregulated. The GMA merely requires registration of wells outside AMA boundaries; no pumping limits or quantification of rights is required. Thus groundwater mining may still be occurring outside AMA boundaries, undermining the GMA's goal of eliminating overdraft and sustainably managing groundwater resources in the state. Until permitting and quantification of rights is extended to all basins in the state, the policy will continue to be reactive rather than proactive, only addressing the problem of overdraft once it has become severe. This regulatory discrepancy also spurred the water farming craze of the 1980s, with significant negative impacts on rural communities and the sustainability of the aquifers underlying rural lands. While other circumstances (both policy changes and additional supply) remedied this problem somewhat, any groundwater marketing framework that borrowed from Arizona's regime would need to address this potential threat to rural third parties through the appropriate internalization of the costs they would incur.

Exempt wells can also pose a threat to efficient groundwater management and the establishment of an efficient water market in Arizona, as in Texas. Exempt wells can have significant drawdown effects both inside and outside AMAs. Even with the registration requirement imposed by the GMA, the DWR does not know exactly how many exempt wells are within the AMAs, hindering it from effectively managing the groundwater beneath these regions. Additionally, while non-exempt wells are required to conduct analyses to determine that the new well will not adversely impact surrounding wells (including exempt wells), no such requirement is placed on drilling exempt wells (Maguire, 2007). Such inequity will only impede the development of an efficient water market by placing additional burdensome transaction costs on non-exempt well drillers.

NEW MEXICO

Water Law

The system of groundwater regulation in place in New Mexico stands almost in direct contrast to Texas's rule of capture approach, effectively placing groundwater under state ownership through the prior appropriation doctrine (Emel, 1992), whereby state waters may be privately appropriated for beneficial use and, in cases of water shortage or declining water tables, priority is given to the most senior right holder. While prior appropriation is a common approach to managing surface water in the West, New Mexico is among the few states that apply the concept to both surface and groundwater.

The State Engineer

Codified water policy emerged in the state in 1905 with the office of Territorial Irrigation Engineer, the forerunner of New Mexico's modern day State Engineer. The

Territorial Irrigation Engineer was responsible for maintaining well records, issuing permits to drill wells, measuring flow and pressure from wells, inspecting wells, and dealing with complaints of waste (Chalmers, 1974). The 1907 Water Code replaced the Irrigation Engineer with the State Engineer, an appointed official in whom broad authority to grant and enforce water rights is vested:

> Before he came, New Mexicans could simply take water they wanted and hope that they wouldn't get sued after the fact…After he came, New Mexicans could take water only if the State Engineer said that they could and only if the State Engineer determined in advance that the new right would not impair existing claims to a common source. (Hall, 2008, p. 246)

The focus of New Mexico's groundwater regulatory system is placed on underground streams, channels, or basins with "reasonably ascertainable boundaries" (NM GW Code, §77-1101). Once the State Engineer has identified these boundaries, he may "proclaim or declare an underground water basin by the issuance of appropriate orders and the publication of a description of the basin boundaries" (Chalmers, 1974, p. 74). Once this is done, the water within the declared basin becomes the property of the State and is subject to appropriation for beneficial use (§77-1101).[23] On land overlying these boundaries, only permitted well users can drill and pump water from the aquifer (Chalmers, 1974). In order to issue permits, the State Engineer must ascertain how much water is available to be appropriated in the basin. Groundwater users in the basin must submit an application to the State Engineer containing information on the location of the well, the use to which the water is put, and the amount of water desired (Smith, 1984). The State Engineer must publish these applications in local newspapers and allow interested parties the opportunity to object to the granting of the application if they

[23] The doctrine of prior appropriation also applies to percolating groundwater (not confined to a basin or underground stream), but permits are not required to pump these unconfined waters (Chalmers, 1974).

believe it might impair their own water rights (Chalmers, 1974). The State Engineer must then determine whether unappropriated water remains in the basin and whether granting the new permit will impair existing water rights (§72-12-3(e)). He may also refuse to grant the permit if it is contrary to the conservation of water or otherwise negatively impacts the public welfare. In keeping with the doctrine of prior appropriation, the right holder with the earliest application date on file is the senior-most right holder (Folk-Williams, 1985).

In 2005, the State Engineer declared all remaining groundwater basins, so that all groundwater within the state now lies in declared basins where these regulations apply (Figure 11) (Brockmann, 2009).

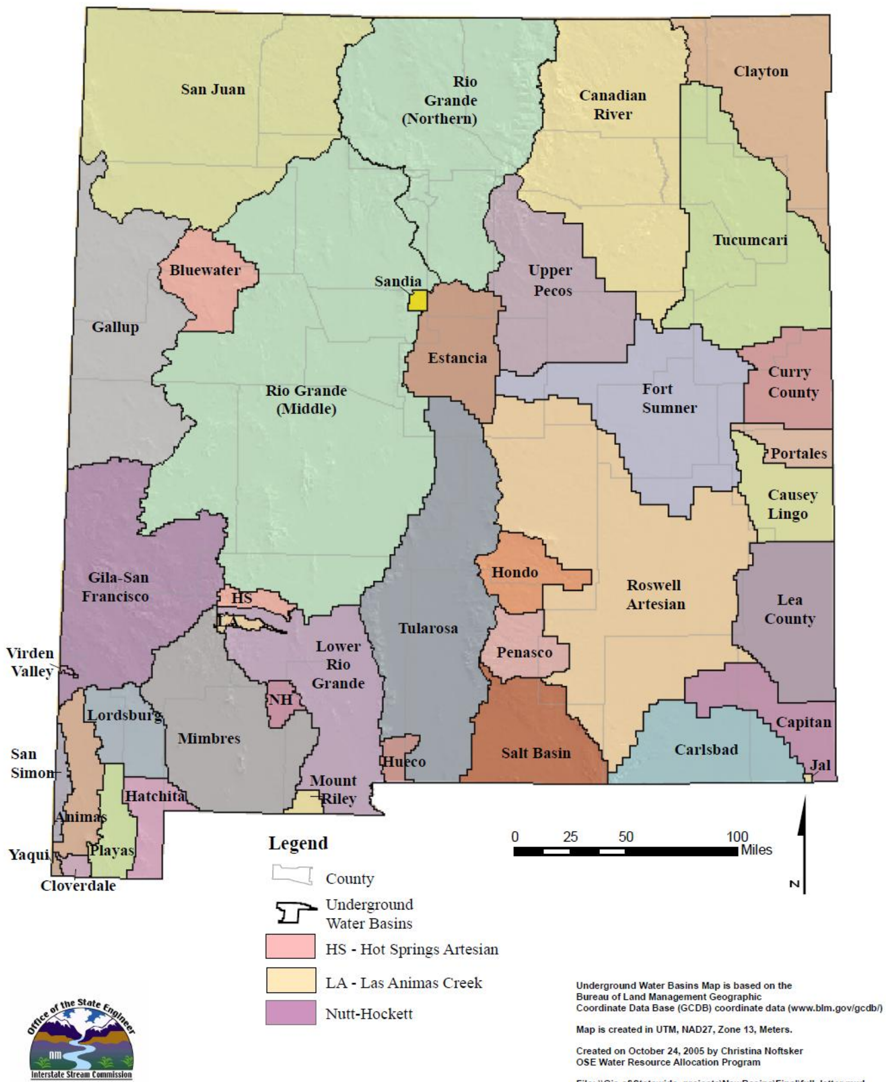


Figure 11: New Mexico's Declared Underground Water Basins (NM Office of the State Engineer)

Exempt Wells

Even within declared basins, however, not all wells are required to go through the entire permitting process. As in Texas and Arizona, certain types of wells are exempted from full permitting requirements. Wells used for domestic and livestock purposes (limited to withdrawals of one acre foot per year) will be granted permits from the State Engineer once the owners file an application (§72-1-1.1).

In 2008, Horace Bounds, Jr. – a farmer in a declared basin that has been closed to further appropriation since 1972 – filed suit against the State Engineer, alleging that the expedited process for granting permits to exempt wells violated the prior appropriation doctrine and impaired the rights of senior permit holders. The district court found in favor of the plaintiff and ruled that the State Engineer had to administer exempt well permits in the same way as all other permits. However, the Court of Appeals reversed the decision, finding that the exempt well regulations do not violate the doctrine of prior appropriation and deferring to the agency's discretion in interpreting a broad statute (Richardson and Dowell, 2012). Because the expedited process requires the State Engineer to grant permits for exempted wells, even in basins where there is no more water to be appropriated, without the customary period for objections by users whose rights will be impaired, the expedited process represents an exemption from typical permit process, not the doctrine of prior appropriation (ibid). The case is now pending before the New Mexico Supreme Court. Although this case most directly affects New Mexico's groundwater management system, it can have implications for other states with exempt well exceptions, including Texas. Proponents of exempt wells might seek to make statutes stronger, to preclude the potential for their constitutionality to be questioned (ibid). If they are successful, proliferation of exempt wells may continue with very little regulation, exacerbating the problem of unmonitored and unregulated withdrawals that undermine the enforceability of the private property rights system in groundwater necessary to foster efficient market activity.

Conjunctive Management of Water Rights

Not only does the State Engineer manage the state's groundwater resources, he is responsible for overseeing the use of surface water as well. In cases where an aquifer is known to be directly connected to a surface water body (contributing to the base flow of a river, for example), the State Engineer must also consider the impacts of any new groundwater withdrawal permits on the rights holders in the connected surface water body. If he determines that to grant the new groundwater right would deplete the base flow of an appropriated stream, the well applicant must purchase and retire surface water rights sufficient to cover the amount of water he is withdrawing from the base flow (Chalmers, 1974). This conjunctive management approach recognizes the fundamental connection between surface and groundwater resources in a way that is highly uncommon throughout the West.

Water Market Activity

The State Engineer plays a central role in water trades as well as initial permits, approving each transfer of ownership, place of use, and purpose of use (Oat and Paskus, 2013).

138 transfers totaling 678,000 acre feet occurred in New Mexico from 1988 to 2009 (WGA, 2012), most from agricultural to municipal users (Oat and Paskus, 2013). However, "strong, formal markets for water rights in New Mexico have not matured" due to physical, legal, and political impediments (ibid, p. 27-1). Although a formal marketing framework has not yet emerged, the demand for water trades in a state where almost all the groundwater resources are already appropriated is high and the legal ability to trade does exist (ibid). While the volume of water traded in New Mexico is the smallest amount of any state considered here, the State Engineer views water trading as the only way to meet future water demands in the state (WGA, 2012).

Under the prior appropriation system currently employed, a water rights holder may sell or lease his rights, and can change the place and purpose of use and point of withdrawal (Saliba, 1987). However, water transfers are still subject to the same permitting requirements that initial applicants are: the seller must be able to show that the proposed transfer will not impair existing water rights, is not contrary to conservation of water, and will not harm the public welfare (Oat and Paskus, 2013). The right's initial priority date is maintained even after the right is sold (Saliba, 1987). Water rights holders can lease their entire right or a portion of it for up to ten years before it may be subject to forfeiture (ibid).

Strengths and Weaknesses

Considered a "pioneer in the regulation of the use of groundwater," New Mexico boasts one of the longest histories of groundwater management in the West (Folk-Williams, 1985, p. 131). Such a long standing system speaks to its efficacy and flexibility, and to be sure, New Mexico's approach to groundwater regulation has several positive implications for marketing. However, as the lack of an institutionalized market indicates, several barriers will need to be overcome before the system can produce a robust groundwater market.

The consolidation of so much authority in the central office of the State Engineer, and in the person of the State Engineer himself, could be highly detrimental to a system of groundwater management if the official was not given the necessary flexibility and insulation from political pressure required to effectively oversee water allocation activities. However, more than one legal scholar views the system as providing adequate authority and flexibility to enable the State Engineer to meet his statutory obligations (Chalmers, 1974; Hall, 2008). For those who view state control as the most stable and beneficial approach to water management, the office of State Engineer is a crucial piece of any regulatory framework (Clark, 1992). For purposes of groundwater marketing, the centralized authority of the State Engineer can help lower transaction costs by reducing legal and regulatory uncertainty – a one-stop-shop of permitting and adjudication of information. Further, because the New Mexico model allows for the conjunctive management of surface water and groundwater, trades between these two media could also be made easier, reducing the bureaucratic layers that a groundwater user is required to penetrate to purchase and retire surface water rights, for example.

From an environmental standpoint, the use of the conjunctive approach helps internalize environmental needs into groundwater allocation decision-making by considering how much an aquifer contributes to a stream's base flow and requiring that amount to be preserved for instream flows.

Other externalities are also addressed in the New Mexico system, as the permitting process allows for opponents of proposed rights or transfers to state their cases. The inability for opponents of exempt wells to voice their concerns represents a failure of this system, however, as third parties negatively affected by the drilling of exempt wells cannot find relief in the permitting process. If the Supreme Court rules in favor of the State in *Bounds v. New Mexico*, this oversight could become institutionalized, presenting a serious obstacle to the state's ability to mount a truly efficient marketing system.

Because all basins were declared in 2005, theoretically all users of non-exempt wells are required to obtain a permit, thus extending the private property rights system to nearly all pumpers. This can help facilitate water markets by ensuring universality and enforceability of rights, allowing users to feel safe in the knowledge that their property rights are secure and any encroachment can be redressed in court. Unfortunately, uncertainty is not completely eliminated, and in fact still pervades certain parts of the system. Although all basins have been declared, not all are adjudicated yet – thus not every well user's rights have been quantified so buyers and sellers may find it difficult to be certain about the actual amount of water available for transfers (Oat and Paskus, 2013).

Concomitantly, metering is not as ubiquitous as it should be, further inhibiting a buyer from being certain about the amount of water available (ibid). This uncertainty complicates the transfer system: although legal barriers can be overcome, "in practice, completing a transfer or lease can be difficult. Sales and leases occur, but the high transaction cost due to the murky nature of the rights can complicate the process" (ibid, p. 27-4). These transaction costs can be further elevated due to the lack of a centralized information clearinghouse or auction forum that might facilitate trades in a formal market. Instead, parties willing to trade must navigate the market on their own to find potential buyers and sellers (ibid).

CALIFORNIA

Although much of California's water demand is met with surface water, groundwater trading has increased in recent decades as increasing demand and prolonged droughts cause many to search for alternative supplies. Unlike the other states that have been discussed, California adopts a correlative approach to managing groundwater rights, in addition to the more familiar doctrine of prior appropriation. The state also oversees one of the most robust systems of ensuring third party effects are minimized, which helps to mitigate externalities but also depresses market activity.

Water Law

Groundwater that forms the subsurface flow of streams and groundwater flowing in defined underground streams are subject to the same doctrine of prior appropriation that informs surface water rights. As in the other states we have discussed, groundwater in California is presumed to be percolating water and forms the main focus of groundwater regulation in the state (Chalmers, 1974). Historically, the English common law doctrine of absolute ownership governed groundwater pumping in California. However, in 1903 the California Supreme Court reached a decision that the Texas courts have yet to make:

> "We cannot perceive how a doctrine [i.e. the absolute ownership doctrine] offering so little protection to the investments in and product of [valuable enterprises and systems of water works], and offering so much temptation to others to capture the water on which they depend, can tend to promote developments in the future or preserve those already made, and therefore we do not believe that public policy or a regard for the general welfare demands the doctrine." (*Katz v. Walkinson*, quoted in Chalmers, 1974, p. 53).

Throwing out absolute ownership, the court suggested replacing the doctrine with a model that combined correlative rights with prior appropriation. The resultant framework, codified in California statute, specifies three types of rights for pumpers of percolating groundwater: overlying rights based on the correlative doctrine, appropriative rights for non-overlying users, and prescriptive rights.

Overlying rights apply to landowners overlying the aquifer. Overlying rights are based on the correlative rights doctrine and the concept of reasonable use: overlying landowners may pump as much water as they can reasonably and beneficially use in relation to the needs of other overlying landowners. All rights are treated equally, with no priority given to senior rights holders (Sawyers, 2005b).

Appropriative rights apply only to surplus water – that is, water that can be withdrawn without contributing to overdraft of the aquifer. Water users who do not own land overlying the aquifer or overlying landowners who use the water on land outside the basin may pump surplus water and put it to beneficial use either inside or outside the basin. These rights are seniority-based, governed by the doctrine of prior appropriation (ibid).

The validity of prescriptive rights has been questioned in at least one court case, and the State Water Resources Control Board holds that they are now virtually unobtainable (SWRCB, 2013a). However, they do represent a singular type of right in groundwater not seen in the other states' frameworks. Prescriptive rights may be obtained when a user continues to pump during obvious overdraft conditions, beginning as a wrongful appropriation of water and ripening into a legitimate right (Bartkiewicz, Kronick, and Shanahan, 2006), much in the same way squatters' rights in land develop (SWRCB, 2013a). Prescriptive rights require a user to pump for at least five consecutive years during a period of water shortage (Bartkiewicz, 2006) and can only be granted by a court of law (SWRCB, 2013a).

Adjudication

None of these water rights require quantification of the amount of water available for each; nor are permits required to pump groundwater. Quantification of rights usually does not occur until the basin is adjudicated to address water shortage issues. During the adjudication process, which is typically overseen by the courts, junior appropriative rights holders often try to prove they have a higher priority and deserve a more senior right by showing they have pumped for at least five years during an overdraft period. If they are able to make this showing, senior appropriative rights holders may be relegated to pumping only the amount that they used during the same period, losing their more privileged place in the appropriative hierarchy. Overlying rights holders, whose rights are based on a correlative approach, could be given rights to a specified quantity of water that reflects their historical use (Bartkiewicz, 2006).

Adjudication is a complicated process, often taking several years to complete. Indeed, water rights adjudications are usually only undertaken for aquifers that have long histories of overdraft (Chalmers, 1974). The courts frequently retain authority to implement and enforce the adjudication order. They may also appoint a watermaster to oversee administration of a basin (Sawyers, 2005b). Once rights have been adjudicated, they may be severed from the land (Bartkiewicz, 2006), adding to the amenability of the California system to groundwater marketing.

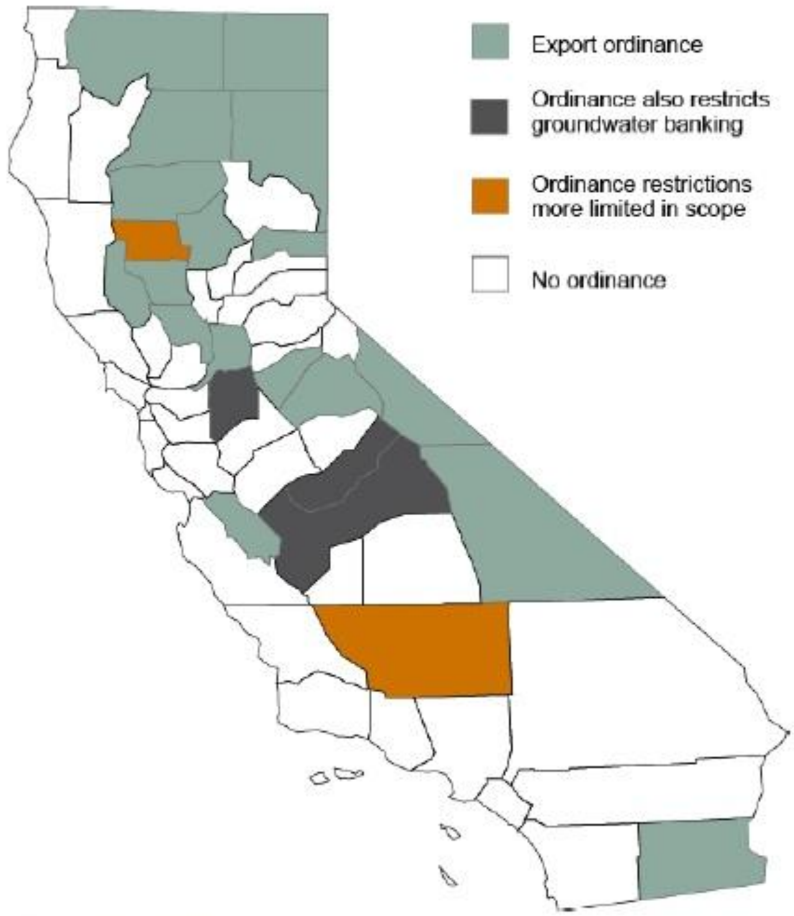
Water rights in California are based on the public trust doctrine, so that no right holder actually has a right to the water itself, but merely a right to *use* the water for some beneficial purpose. If the State finds that the use to which a certain amount of water is being put is not in the public interest, or that another use would be more beneficial, it is required to reallocate the water to the more beneficial use. Thus, the conventional concept of a vested private property right in water is absent from the California system (Sawyers, 2005b).

State and Local Groundwater Management

California lacks a statewide regulatory framework for groundwater management; instead local control exists in the form of groundwater management districts and county authority – making the California system more reminiscent of Texas's in this instance than the more centralized framework of either Arizona or New Mexico. At the state level, the State Water Resources Control Board (SWRCB) controls permitting and in some cases may oversee adjudication of overdrafted basins. The SWRCB is also responsible for enforcement of the state's beneficial use requirements and has the authority to investigate allegations of misuse or waste and to seek administrative or judicial remedies. Most critically from a water marketing perspective, temporary water transfers require SWRCB approval (SWRCB, 2013b).

At the local level, over twenty different types of local water agencies are authorized by various statutes to provide water to agricultural, municipal, or industrial users. Under Assembly Bill (AB) 3030, many of these local agencies are also empowered to develop groundwater management plans, which may include provisions relating to preventing saltwater intrusion, subsidence, water level monitoring, and levying fees to cover the expenses of various projects (such as for storage, recharge, or recycling) (CA Water Code, §10753.7). Currently, 149 local water agencies have developed groundwater management plans. Although AB 3030 does allow agencies to place restrictions on groundwater withdrawals, this power is extended only during limited circumstances. Thus groundwater management plans tend to focus more on monitoring and recharge efforts, rather than on ways to manage demand to prevent overdraft (Sawyers, 2005a).

Counties have created another means of local control over groundwater management and transfers through the adoption of local ordinances. Their ability to do so was upheld by the California courts in 1994 as a legitimate exercise of police power in the absence of comprehensive state regulation of groundwater (Hanak, 2003). As of 2002, 38 percent of the state's counties had adopted some type of ordinance placing restrictions on exports of groundwater outside the county. Most of these counties are rural, indicating that third party effects on agriculturally based economies are major concerns (PPIC, 2003). These ordinances usually require exporters to obtain a permit, which necessitates an environmental review under the California Environmental Quality Act (CEQA). The CEQA review process is arduous, requiring multiple studies and several reviews by various agencies (Hanak, 2003). The extent to which these requirements have dampened market activity by creating impediments to water trades is discussed at greater length in the “Strengths and Weaknesses” section.



SOURCE: Hanak, 2003.

NOTE: Figure shows ordinance status as of 2002. To our knowledge, no additional county groundwater ordinances have been adopted since then. Kern County's ordinance is limited to the southeast portion of the county within the South Lahontan hydrologic region. (Figure 12 shows this regional breakdown.) Glenn County's ordinance was updated in 2000 and now relies on basin management objectives that do not automatically restrict groundwater exports.

Figure 12: County Ordinances that Restrict Water Exports (Hanak and Stryjewski, 2012, p. 17)

Water Market Activity

Water marketing in California began in the 1970s with state encouragement and took hold in the late 1980s and 1990s as the state experienced several droughts (PPIC, 2003). Although state officials have tried to incentivize water trading in the state through policies and changes to statutes and direct purchases of water (Hanak and Stryjewski, 2012), California's market activity has stagnated in the last decade (Williams, 2012). This recent slowdown can be attributed to the complicated institutional review process (Hanak and Stryjewski, 2012).

From 1988 to 2009 the total volume of water traded amounted to 13.3 million acre feet, the majority of which consisted of leases (WGA, 2012). In 2010, water transfers totaled two million acre feet, representing five percent of the state's water use (Hanak and Stryjewski, 2012). Short-term leases and trades for environmental needs dominated water trades during the 1980s and 1990s (PPIC, 2003), but since 2003 long-term transfers have gained a larger share of the water market (Hanak and Stryjewski, 2012). Municipal demand dominates these transfers, with transfers for environmental needs increasing in absolute terms and declining only in percentage points (ibid). According to Hanak (2012), the dominance of sales and long-term leases indicates that the California water market is maturing: "[t]hese transfers generally involve more complex negotiations and more in-depth environmental documentation" (p. 24).

As the market matures, however, market growth has also slowed. While part of this stagnation is the result of a lack of adequate infrastructure,[24] much of the problem (especially for groundwater transfers) can be linked to tighter restrictions and more complex approval processes. While some of these added restrictions address

[24] This issue pertains mostly to surface water transfers as pumping restrictions in the Delta region – a hub of conveyance infrastructure through which water traveling north-south or east-west must pass – initiated to protect endangered fish species in 2007 have limited the volume of water that can move through the system (Hanak & Stryjewski, 2012).

environmental and third party externalities,[25] some make the process so arduous that truly beneficial transactions are prevented:

> "[W]ater market development has been hindered by the fragmentation of the water market, with different types of water rights and contracts subject to different types of approval. These differences tend to limit market activity even when it would be economically and environmentally beneficial to engage in trading." (Hanak and Stryjewski, 2012, p. 26).

Thus, while the California marketing system is relatively robust, it is prevented from realizing its full potential by several impediments including restrictions on exports, timid groundwater management plans that tend not to address limiting overdraft, and overly burdensome approval processes.

[25] Restrictions on land fallowing (taking agricultural land out of production to save the water that would be used to irrigate it) have been implemented for both environmental and economic reasons (Hanak and PPIC brief). Limitations on using diesel-powered pumps for groundwater (due to air quality issues) have also restricted some groundwater transfers. (Hanak 2012 25).

Chapter Five: Recommendations for Establishing Groundwater Markets in Texas

The preceding discussion of various water marketing systems in place in the Edwards Aquifer, Arizona, New Mexico, and California offers guidance on what characteristics should define a successful groundwater market model that could be adopted throughout Texas. The following chapter outlines several recommendations for altering the current legal and regulatory framework governing groundwater in Texas to make the system more amenable to efficient marketing activity. If Texans begin to seriously consider establishing statewide water markets, more research should be undertaken that surveys a broader range of water marketing and regulatory systems in other regions and nations before formal institutions are developed. It is important to keep in mind that this study encompassed a limited range of existing frameworks through qualitative analyses of four case studies and that the scope of this policy analysis was limited to intrastate transfers of groundwater. Further research into surface water regulation and markets and interstate transfers should inform any future discussions of water marketing in Texas. Additionally, all quantitative data regarding water transfers combines both surface and groundwater transfers unless otherwise noted.

ELIMINATING THE RULE OF CAPTURE AND ADJUDICATING WATER RIGHTS

The rule of capture represents a serious obstacle to the formation of an efficient market regime as it effects group ownership of a common pool resource, neither protecting individual rights from encroachment nor internalizing the myriad external costs that accrue to neighboring pumpers, future pumpers, and the environment. In fact, as discussed in Chapter Two, the rule of capture system may be said to actually incentivize inefficient use through a tragedy-of-the-commons-style "race to the pump" that drains an aquifer more quickly than use under an adjudicated property rights system would. The inappropriateness of the rule of capture for establishing efficient management of groundwater resources is evidenced by the fact that Texas is the last state to still employ this doctrine in groundwater regulation. Therefore, the elimination of the rule of capture doctrine and its replacement with a system of adjudicated private property rights in groundwater is a necessary first step in establishing any widespread marketing system.

To be sure, adjudicating rights to even one basin is a lengthy and complex process and complete adjudication of the state's nine major and 21 minor aquifers could take decades. Combine the typical complexities of adjudication with the strong political opposition from entrenched interests (such as existing pumpers and agricultural interests) that adjudication proceedings are likely to engender and the establishment of an adjudicated system of property rights in groundwater statewide is no easy task. For these reasons, the Texas approach might consider California's mechanism of adjudication, whereby property owners in a basin initiate proceedings by bringing suit. At the other end of the spectrum, New Mexico's State Engineer classified all basins in the state as declared basins subject to prior appropriation in 2005, adjudicating all remaining undeclared basins in one declaration. This process is undoubtedly much quicker than the ad hoc California approach and would enable groundwater to be used more efficiently without the long history of aquifer mining that usually characterizes grassroots initiations of adjudication proceedings, but given Texas's tradition of localized groundwater control and aversion to centralized oversight, the New Mexico approach may prove more difficult to mount in Texas.

Approaches to Adjudicating Basins

This report has alluded to the possibility of more frequent drought conditions in Texas in the future and the need for adhering to the concept of safe yield in groundwater management, both for environmental needs and to increase the longevity of the resource. In light of this, the system of adjudication employed in various basins can have a direct impact on the ability of well users to maintain safe yield. Vaughn and Emerson (1997) discuss two different approaches to allocating water rights in the Edwards Aquifer and their implications for water marketing. Under the seniority system, based on the prior appropriation doctrine, junior rights holders would be the first to suffer mandatory reductions during drought periods. This approach may not be the most amenable to achieving safe yield, however, as junior rights holders may race "to pump their adjudicated quantity before their class is declared ineligible to pump" through drought restrictions (Anderson and Hill, 1997, p. 180). The seniority system with mandated reductions for junior pumpers can also lead to overwatering and hoarding unused water (Anderson and Hill, 1997).

This approach has been taken to adjudicating rights in California basins, with the result that junior pumpers often try to prove their seniority by showing evidence of large amounts of sustained pumping during the historical period (discussed in Chapter Four), which may have negative effects on preventing overdraft in heavily pumped aquifers. In New Mexico, the prior appropriation approach to adjudication leaves open the possibility for senior users to call on a junior user (such as a municipality) to cease pumping during times of drought. Although this does not often occur, there is speculation that the mere possibility of this demand contributes to an uncertainty among junior users that makes water rights more difficult to trade (Oat and Paskus, 2013).

A better approach, Vaughn and Emerson argue, is the shares system of adjudication, in which users are allotted a *proportion* of the water available, not a fixed quantity. This approach works particularly well with stochastic water sources (ones that are highly variable in the amount of water available) (Anderson and Hill, 1997). Under such a proportional system, different pumping regimes would be in place for wet years and dry years, with the amount of water available to pumpers determined at a certain time of year and the physical amount of water allotted to each right holder based on this overall available quantity (Votteler, personal interview, January 31, 2013).

In the Edwards, a seniority based approach was taken that submits users to a pro rata reduction during critical management periods (discussed in Chapter Three). This approach has worked effectively for the Edwards, and could be applied to other aquifers, especially where recharge is less variable. However, the shares system does hold an advantage over the seniority based approach: all rights are identical, which may facilitate trading as potential buyers will not be hesitant to purchase junior rights subject to mandatory reductions or cut offs (Anderson and Hill, 1997).

Well Metering

Along with adjudication of rights, statewide metering of wells will be required to enforce these water rights. As discussed in Chapter One, private property rights in groundwater work best when rights holders are secure in the knowledge that their rights – and the water those rights afford them – are safe from encroachment by other pumpers. When this knowledge is not available, water market activity can be depressed. This phenomenon can be seen in New Mexico, where a lack of widespread metering contributes to uncertainty about the amount of water available for trades (Oat and Paskus, 2013). Thus, each permitted well must be metered to ensure that the pumper is using only the amount of water allotted him by his water right and that adequate information is available on the amount of water available for trades. While the concept of metering wells has not been met with much favor in Texas in the past,[26] some program of comprehensive monitoring of water use is central to a successful market framework and should form a part of any attempt to establish markets in Texas.

CENTRALIZED OVERSIGHT WHILE MAINTAINING LOCAL CONTROL

While each state studied here (Arizona, New Mexico, and California) takes a different approach to groundwater regulation, the one characteristic they all share is some centralized state-level office that oversees some part of the adjudication and permitting processes. Even in California, where groundwater management districts have the primary responsibility for overseeing water regulation and marketing, the State Water Resources Control Board (SWRCB) controls permitting and, in some cases, adjudication (see Chapter Four). The benefits of such a centralized body include a comprehensive clearinghouse of marketing and withdrawal information and stability and uniformity of groundwater management. Given Texas's history of localized control over groundwater management decisions, a highly centralized system like New Mexico's State Engineer may not be the most appropriate framework for Texas, however. Instead, a system reminiscent of California's may be more feasible as local groundwater districts retain control over permitting and trading. In a Texas framework, the Texas Water Development Board (TWDB) could act as the statewide overseer of permitting, reporting, and trading, serving as a comprehensive clearinghouse of information that potential

[26] Nor has it had much success in the present: the fate of Senator Seliger's SB 272 illustrates the general unwillingness of the groundwater management community to initiate widespread metering. The original bill merely sought to require reporting of groundwater use to GCDs and the TWDB for pumpers outside GCD boundaries, but was so weakened in the Senate Natural Resources committee that the version ultimately passed by the Senate is completely ineffectual and does not require any additional reporting on water use to be made.

buyers, sellers, and lessors could utilize to obtain the information necessary to facilitate water trades. With more staff and financial resources than many GCDs, the TWDB might also enforce property rights, with the ability to investigate and prosecute violations of permitting requirements.

The retention of local control in the GCDs is important in creating/fostering public support for a water marketing regime in a state whose political culture emphasizes local authority and individualism, but it is also important given the wide variation in aquifer types across the state. The state's nine major aquifers alone portray a wide geologic variety, ranging from sandstone to limestone to alluvial sediment; some have high porosity and some low; some are confined, or under pressure, while some are unconfined. An even broader range of geologic characteristics are found among the 21 minor aquifers. From a socioeconomic perspective, the variability is even more striking: some aquifers are heavily utilized by agriculture, like the Ogallala, where 95 percent of the groundwater pumped is used for irrigation, while others mostly supply municipalities, as is the case for the Hueco-Mesilla Bolsons Aquifer, where nearly 90 percent of pumped water goes toward municipal supplies (George et. al, 2011). With so many different environmental, social, and economic characteristics, one overarching water marketing and adjudication strategy may not effectively address the needs of each aquifer. Determinations of safe yield, desired future conditions, and other water planning benchmarks will necessarily differ across aquifers. Thus a retaining a local approach overseen by GCDs can ensure that the permitting and transfer of groundwater rights takes into account this wide variation.

Ensuring GCDs Can Effectively Oversee Groundwater Resources and Markets

As discussed in Chapter Two, GCD boundaries are drawn largely along political and jurisdictional lines. Boundaries of GCDs should be amended to follow the hydrogeologic boundaries of the aquifers underneath them, preferably either encompassing more than just one county or collaborating with adjacent GCDs to cooperatively manage their shared aquifer.

Further, GCDs should exercise their statutory authority to register, permit, and meter wells, establishing pumping limits if necessary to achieve safe yield. In doing so, GCDs could become the primary administrators of localized groundwater markets, working in tandem with the TWDB on adjudication and enforcement issues.

DEALING WITH EXTERNALITIES

Factoring in Environmental Needs

As previously discussed, the Arizona system is based on the concept of maintaining safe yield for aquifers in active management areas. In Texas, this sustainable pumping goal should form the basis of the GCDs' desired future conditions to ensure that the groundwater resource is available to pumpers as long as possible. As Mary Kelly (2004) stated, basing groundwater use on sustainable yield will simultaneously provide for environmental needs by incorporating aquifer and spring habitat or base flow needs into the safe yield calculation. Maintaining adequate water for spring habitats formed the impetus for the Edwards Aquifer Authority and may protect numerous other species that thrive in the many other aquifers and aquifer-fed springs and streams across the state.

By assessing and incorporating these needs into their DFCs, GCDs can also mitigate the negative externalities that groundwater marketing might have on the environment. Other environmental issues like aquifer compaction, land subsidence, and saltwater intrusion can also be considered in this determination of safe yield, helping GCDs to fulfill their statutory obligations to prevent subsidence and maintain water quality in a proactive, rather than reactive, manner.

Internalizing Third Party Effects

Additionally, some consideration of the impacts to third parties must also be included in the calculation of safe yield and subsequent determinations of DFCs. In New Mexico, the opportunities for contesting the permitting of new wells provide potentially affected third parties a way to factor the costs they would incur into the decisionmaking process. In Texas, this system could be incorporated into existing water transfer regulation. SB 2 (2001), which prohibits placing more stringent controls on exports than on intra-basin trades has beneficial implications for water markets in that it does not distort the market by raising transaction costs only for a certain type of water transfers, but the legislation should be amended to allow users in the transferring district to contest a proposed trade if they can show they would be harmed by the trade. Additionally, as discussed in Chapter Four, the current expedited approval process for exempt wells in New Mexico poses problems for ensuring that all affected third parties are afforded these opportunities; the application of such a system in Texas should make sure to provide avenues even for those potentially affected by exempt wells.

However, attempts at internalizing third party costs can be carried too far, as the California example illustrates. To be effective, the particular system of third party protection adopted in Texas cannot increase transaction costs to the point that beneficial transfers are disincentivized and market activity depressed. This may mean a concerted effort to streamline approval processes for various types of permits, instead of subjecting permits from different aquifers or for diverse uses to different approval requirements, which has been cited as an impediment to trade in the California market (Hanak and Stryjewski, 2012).

Finally, environmental and third party impacts could be more holistically considered if groundwater and surface water were managed conjunctively. While the New Mexico system hints at such a management scheme by allowing the State Engineer to take surface water impacts into account when permitting new groundwater rights, no system yet manages both surface and groundwater rights in a way that directly acknowledges the myriad connections and interdependencies between the two resources. While schemes for initiating conjunctive water resources management is outside the scope of this report, further research into the viability of groundwater or surface water markets in Texas should consider methods of employing conjunctive management. Many externalities can remain unmitigated when groundwater, or surface water, is managed in isolation, rather than in a wider framework that acknowledges the ways water moves through the human and natural environments.

EXPECTED GAINS FROM EXTENDED USE OF WATER MARKETS IN TEXAS

Because Texas is a unique state with 30 different aquifers that vary in size, type, and the environmental and human activity they support, quantifying the specific benefits that might accrue to Texans via an established statewide groundwater market is difficult. However, one can look to the success of the state's few existing water markets as indications of the potential gains that could occur.

The surface water market that thrives along the lower Rio Grande River is widely considered to be an effective means of reallocating water in an arid region experiencing some of the state's fastest rates of growth. Chang and Griffin (1992) found that the loss to agricultural water rights holders who sold their rights to growing municipalities was much less than the substantial benefit that the municipalities gained from the transaction (net benefits ranged from $4,751 – $15,106). Qualitatively, Griffin (2011) asserts that the water market's success is reflected in its ability to reallocate agricultural water to municipal and industrial uses while maintaining the health of the agricultural sector. Further, despite the explosive population growth experienced by the area over the past few decades, no new supply projects have been constructed in forty years (Griffin, 2011).

In both the Rio Grande Valley and the Edwards Aquifer, the transformation of traditional water right regulation to a system allowing for transfer of water rights has resulted in the clear reallocation of water to more valuable uses, effecting the "[advancement of prosperity] in spite of growing water scarcity," while simultaneously avoiding the construction of expensive new supply projects (Griffin, 2011, p. 62). By establishing the Edwards Aquifer Authority and allowing it to manage water transfers, "the Texas legislature was able to build considerable flexibility and resilience into the region's system," and establish a water allocation mechanism whose "achievements appear to be high relative to more restrictive or regulatory approaches" (ibid). By incorporating the recommendations discussed above, it is to be expected that the establishment of future groundwater markets in the state would effect the same positive results.

CONCLUSION

As we move further into the 21st century, pressing concerns about increased water demand, drought conditions, and a lack of opportunities for large new supply projects are prompting policymakers, economists, and even the general public to consider where our water may come from in the future. Water marketing can be one method – used in conjunction with conservation, technological solutions like desalination, and additional supply projects – to meet our growing needs in the face of finite supplies. Although water markets are not currently widely utilized in Texas, the potential to institutionalize a statewide system of markets does exist. Drawing from lessons learned in Arizona, New Mexico, and California, as well as from the only formal groundwater market in Texas in the Edwards Aquifer, several best practices are revealed that should be considered in developing a market framework in Texas groundwater resources. While political, legal, and cultural impediments may make the road to establishing such markets less than smooth, Texas's willingness to experiment with valuing environmental needs and instream flows, regional water planning approaches, and the initiation of water markets in certain areas of the state (including the Edwards Aquifer) show that change is possible. If in fact, as Ronald Griffin states, the "free lunches of the original Texas water endowment have been consumed" (2011, p. 238), the transition to widespread groundwater marketing may represent the next epoch in water regulation in the state.

References

Anderson, T., & Hill, P. (Eds.) (1997). *Water Marketing – The Next Generation.* Lanham: Rowman & Littlefield.

Anderson, T., & Snyder, P. (1997). *Water Markets: Priming the Invisible Pump.* Washington, DC: Cato Institute.

Arizona Dept of Water Resources. (2013). "Overview of the Arizona Groundwater Management Code." Retrieved Apr 29, 2013 from http://www.azwater.gov/AzDWR/WaterManagement/documents/Groundwater_Code.pdf.

Arizona Revised Statutes. Title 45 (2012).

Avery, C., Consoli, C., Glennon, R., & Megdal, S. (2007). "Good Intentions, Unintended Consequences: The Central Arizona Groundwater Replenishment District." *Arizona Law Review.* 49, 339-360.

Bartkiewicz, Kronick, & Shanahan, PC. (2006). *A Summary of the California Law of Surface Water and Groundwater Rights.* Retrieved Apr 29, 2013 from http://www.co.sutter.ca.us/pdf/pw/wr/gmp/WaterRightsSummary.pdf.

Boadu, F.O., McCarl, B.M., & Gillig, D. (2007). "An Empirical Investigation of Institutional Change in Groundwater Management in Texas: The Edwards Aquifer Case." *Natural Resources Journal*. 47, 117-164.

Brock, L. & Sanger, M. (2003). *Spotlight on Groundwater Conservation Districts in Texas.* Austin: Environmental Defense.

Brockmann, J.C. (2009, October). *Overview of New Mexico's Groundwater Code.* Paper presented at 27th Biennial Groundwater Conference, Sacramento, CA.

California Water Code. Division 6 Part 2.75. (2012).

Center for Climate and Energy Solutions. (2012). (The 2011 Texas Drought in a Historical Context." Retrieved November 25, 2012. http://www.c2es.org/blog/huberd/2011-texas-drought-historical-context

Chalmers, J.R. (1974). *Southwestern Groundwater Law.* Tucson: University of Arizona.

Chang, C., & Griffin, R.C. (1992). "Water Marketing as a Reallocative Institution in Texas." *Water Resources Research.* 28(3), 879-890.

Clark, I. (1992). "What Authority Should Reside in the State Engineer? New Mexico as a Case Study." *Natural Resources Journal*. 32, 467-486.

Current Results.com (2004). "Average Annual Precipitation by State." Retrieved Apr 22, 2013 from http://www.currentresults.com/Weather/US/average-annual-state-precipitation.php.

Colby, B.G., McGinnis, M.A., & Rait, K. (1989). “Procedural Aspects of State Water Law: Transferring Water Rights in the Western States.” *Arizona Law Review.* 31(4), 697-720.

Easter, K. W., Rosegrant, M.W., & Dinar, A. (1998). *Markets for Water: Potential and Performance.* Norwell, MA: Kluwer Academic Publishers.

Edwards Aquifer Authority. (2010). *Edwards Aquifer Authority Groundwater Management Plan 2010-2015.* San Antonio: EAA.

Edwards Aquifer Authority. (2012). *Hydrologic Data Report for 2011.* San Antonio: EAA.

Emel, J. (1992). “Ideology, Property, and Groundwater Resources.” *Political Geography*. 11(1), 37-54.

Environmental Protection Agency. (2000). “Sole Source Aquifer Designations in EPA, Region 9.” Retrieved on Apr 29, 2013 from http://www.epa.gov/region9/ water/groundwater/ssa-pdfs/ssafact.pdf.

Evans, A. (2010). “The Groundwater/Surface Water Dilemma in Arizona: A Look Back and a Look Ahead Toward Conjunctive Management Reform.” *Phoenix Law Review.* 3, 269-292.

Folk-Williams, J. A., Fry, S.C. & Hilgendorf, L. (1985). *Western Water Flows to the Cities.* Washington DC: Island Press.

Frazier v. Brown. (1861). 12 Ohio St. 294

Gisser, M. & Sanchez, D.A. (1980). “Competition versus Optimal Control in Groundwater Pumping.” *Water Resources Research.* 16(4), 638-642.

Gopalakrishnan, C. (1973). “The Doctrine of Prior Appropriation and its Impact on Water Development.” *American Journal of Economics and Sociology*. 32(1), 61-72.

Galbraith, K. (2012, Mar 18). “Texas Farmers Battle Ogallala Pumping Limits.” *Texas Tribune.* Retrieved Apr 29, 2013 from http://www.texastribune.org/2012/03/18/ texas-farmers-regulators-battle-over-ogallala/.

George, P. G., Mace, R.E., & Petrossian, R. (2011). *Aquifers of Texas.* Austin: Texas Water Development Board.

Griffin, R. C. (Ed.) (2011). *Water Policy in Texas: Responding to the Rise of Scarcity* Washington DC: RFF Press.

Griffin, R.C. & Boadu, F.O. (1992). “Water Marketing in Texas: Opportunities for Reform.” *Natural Resources Journal.* 32, 265-288.

Hall, G.E. (2008). “The First 100 Years of the New Mexico Water Code.” *Natural Resources Journal.* 48, 245-256.

Hanak, E. (2003). *Who Should Be Allowed to Sell Water in California? Third Party Issues and the Water Market.* San Francisco: Public Policy Institute.

Hanak, E., & Stryjewski, E. (2012). *California's Water Market by the Numbers: Update 2012.* San Francisco: Public Policy Institute.

Hansen, J.K. (2012). "The economics of optimal urban groundwater management in southwestern USA." *Hydrogeology Journal.* 20, 865-877.

Hearne, R.R., & Easter, K.W. (1997). "The economic and financial gains from water markets in Chile." *Agricultural Economics*. 15, 187-199.

Henry, T. (5 Feb, 2013). "For Texas Legislature, What a Difference No Rain Makes." *State Impact Texas.* Retrieved Apr 29, 2013 from http://stateimpact.npr.org/texas/2013/02/05/for-texas-legislature-what-a-difference-no-rain-makes/.

House Bill 1763, 79th Texas Legislature. (2005).

Houston & Texas Central Railway Co v. East. (1904). 98 Tex. 146, 81 S.W. 279.

Hutcins, Wells A. (1961). *The Texas Law of Water Rights.* Austin: Texas Board of Water Engineers.

Ingram, H., & Oggins, C.R. (1992). "The Public Trust Doctrine and Community Values in Water." *Natural Resources Journal.* 32, 515-538.

Kelly, M. (2004). *A Powerful Thirst: Water Marketing in Texas.* Austin: Environmental Defense.

Landry, C. J. (2000). *A Free Market Solution to Groundwater Allocation in Texas: A Critical Assessment of the House Natural Resources Committee Interim Report on Groundwater.* Austin: Texas Public Policy Foundation.

Lesikar, B., Kaiser, R., & Silvy, V. (2002). *Questions about Texas Groundwater Conservation Districts.* College Station: Texas A&M University.

Maguire, R. P. (2007). "Patching the Holes in the Bucket: Safe Yield and the Future of Water Management in Arizona." *Arizona Law Review.* 49, 361-384.

New Mexico Statutes. Ch 77 (2011).

Oat, J., & Paskus, L. (2013). "Water Marketing in New Mexico." *Water Matters!* Albuquerque: University of New Mexico School of Law. Retrieved Apr 29, 2013 from http://uttoncenter.unm.edu/pdfs/water-matters-2013/water%20marketing%20in%20NM.pdf.

Peacock, B.E. (1994). *Complying with the Arizona Groundwater Management Act: Policy Implications.* Doctoral dissertation: University of Arizona.

Public Policy Institute of California. (2003). *Managing California's Water Market: Issues and Prospects.* 74, 1-2.

Richardson, J.J., & Dowell, T. (2012). "The Implications of Bounds v. State of New Mexico." *Journal of Contemporary Water Research & Education.* 148, 17-23.

Saliba, B., Bush, D.B., & Martin, W.E. (1987). *Water Marketing in the Southwest: Can Market Prices be used to evaluate Water Supply Augmentation Projects?* Fort Collins: US Forest Service.

Sawyers, G.W. (2005a). *Recent Regulatory Actions Affecting Agricultural Water Supplies in California.* Davis: UC Davis Agricultural Issues Center. Retrieved on Apr 29, 2013 from http://www.aic.ucdavis.edu/events/outlook05/Sawyer_Regulatory.pdf.

Sawyers, G.W. (2005b). *A Primer on California Water Rights.* Davis: UC Davis Agricultural Issues Center. Retrieved on Apr 29, 2013 from http://www.aic.ucdavis.edu/events/outlook05/Sawyer_primer.pdf.

Schaffer, R.G. (2009, Aug). *Davis v. Agua Sierra Resources: Bringing Some Clarity to Groundwater Rights in Arizona.* Paper presented at 17th Annual Arizona Water Law Conference, Phoenix, AZ. Retrieved on Apr 29, 2013 from http://www. lrlaw.com/files/Publication/c602f55f-0f57-431b-b546 0b99108753b4/ Presentation/PublicationAttachment/c624b92e-1c10-4a5e-9c9e-c77b9f76594a/SchafferFinalFormat.pdf.

Smith, Z.A. (1984). "Centralized Decisionmaking in the Administration of Groundwater Rights: The Experience of Arizona, California and New Mexico and Suggestions for the Future." *Natural Resources Journal.* 24, 641-688.

South Central Texas Water Advisory Committee. (2010). *Report on the Effectiveness of the Edwards Aquifer Authority.* Austin: SCTWAC.

State Water Resources Control Board. (2013a). *Water Rights: Frequently Asked Questions.* Retrieved on Apr 29, 2013 from http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml.

State Water Resources Control Board. (2013b). *The Water Rights Process.* Retrieved on Apr 29, 2013 from http://www.waterboards.ca.gov/waterrights/board_info/ water_rights_process.shtml.

Swaney, J. A. (1988). "Trading Water: Market Extension, Social Improvement, or What?" *Journal of Economic Issues.* 22(1), 33-47.

Texas Water Code. Ch. 36 (2011).

Texas Water Development Board. (2003). *A Texan's Guide to Water and Water Rights Marketing.* Austin, TWDB.

Texas Water Development Board. (2012). *Water for Texas.* Austin: TWDB.

Tinker, S.W. (2012). *Oil & Gas Water Use in Texas*. Austin: University of Texas.

US Census. (2011a). *Cumulative Estimates of Resident Population Change for the United States, Regions, States, and Puerto Rico and Region and State Rankings: April 1,* *2010 to July 1, 2011*. Retrieved Apr 22, 2013, from http://www.census.gov/popest/data/state/totals/2011/

US Census. (2011b). "Texas Gains the Most in Population Since the Census." Retrieved Apr 22, 2013 from http://www.census.gov/newsroom/releases/archives/population/cb11-215.html

Vaux, H.J., & Howitt, R.E. (1984). "Managing Water Scarcity: An Evaluation of Interregional Transfers." *Water Resources Research.* 20(7), 785-792.

Votteler, T. (1998). "The Little Fish that Roared: The Endangered Species Act, State Groundwater Law, and Private Property Rights Collide over the Texas Edwards Aquifer." *Environmental Law*. 28, 845-905.

Votteler, T. (2000). *Water from a Stone: The Limits of the Sustainable Development of the Texas Edwards Aquifer.* Doctoral dissertation, Texas State University.

Western Governors' Association. (2012). *Water Transfers in the West.* Denver: Western Governors' Association.

Weinburg, M., Kling, C.L., & Wilen, J.E. (1993). "Water Markets and Water Quality." *American Journal of Agricultural Economics.* 75(2), 278-291.

Wilder, F. (2012, Feb 25). "The Texas Supreme Court Turns Water into Oil in a Landmark Groundwater Decision." *Texas Observer.* Retrieved Apr 22, 2013 from http://www.texasobserver.org/the-texas-supreme-court-turns-water-into-oil-in-a-landmark-groundwater-decision

Whitford, A.B., & Clark, B.Y. (2007). "Designing Property Rights for Water: Mediating Market, Government, and Corporation Failures." *Policy Sciences*. 40(4), 335-351.

Woodard, G.C. & Checchio, E. (1989). "The Legal Framework for Water Transfers in Arizona." *Arizona Law Review.* 31, 721-744.