GROUNDWATER GOVERNANCE IN AMERICA

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Groundwater governance in the Arab World

Alvar Closas, François Molle

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Foreword

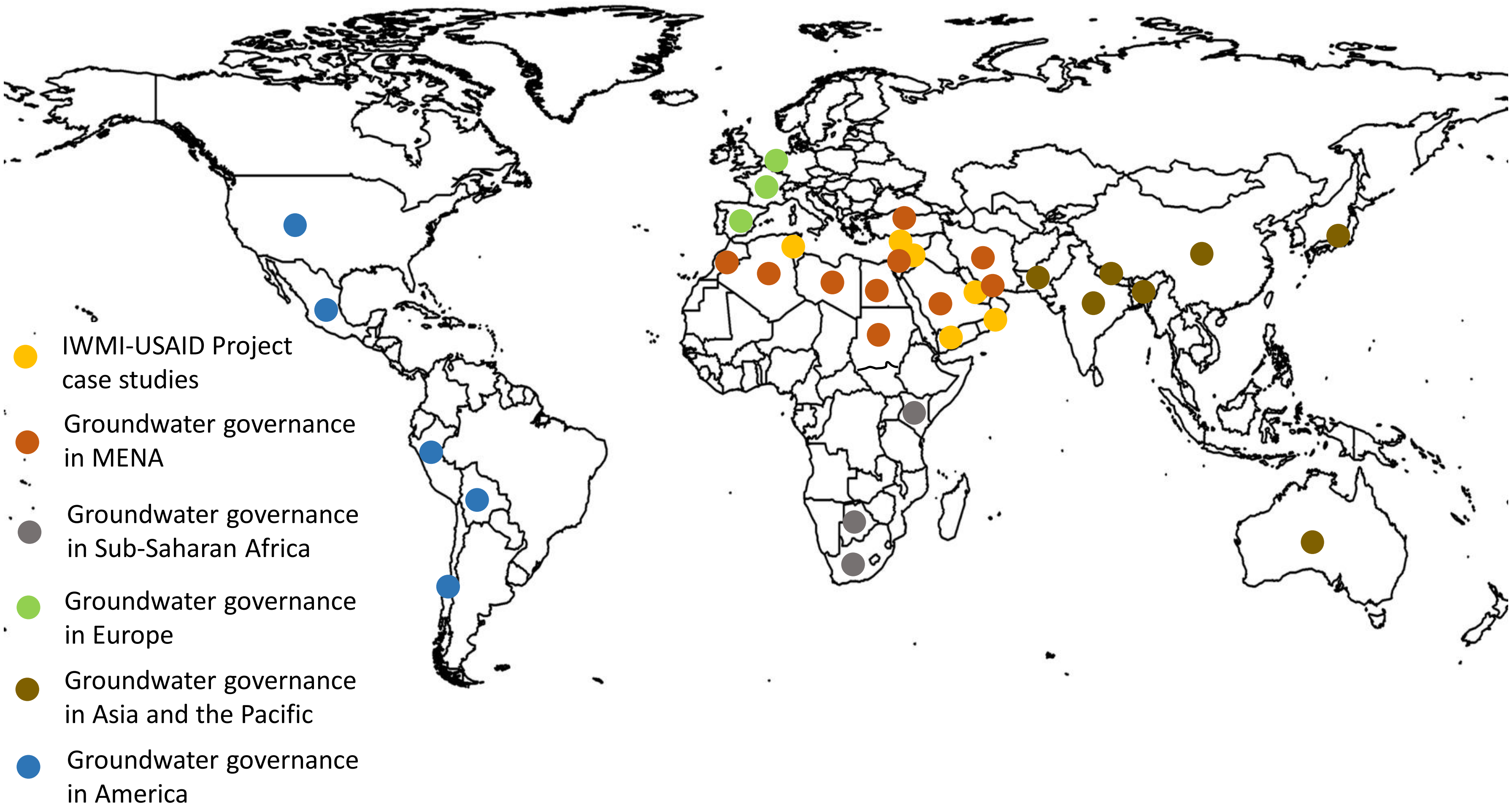
This report on groundwater governance in America is part of a series of five regional reports arising from a research initiative undertaken by the International Water Management Institute (IWMI) and funded by USAID aiming to address the challenges posed by the unsustainable use of groundwater in the Middle East and North Africa (MENA) region (Figure 1). Groundwater over-abstraction is a phenomenon threatening the sustainable economic and social development of the countries on the southern side of the Mediterranean and the control and management of over-abstraction has become a clear challenge for policy-makers, managers and academics in the region. This broader research exercise is aimed at presenting different governance problems and challenges that exist around the world regarding groundwater and inform potential future management and policy pathways in the MENA region.

The reason for this report on groundwater governance in America arises out of the necessity to examine, at various scales, existing cases of groundwater regulation and management so that policy discussions, effective solutions, and mitigation measures to the groundwater crisis may be found. This report brings to the attention of the MENA region the policy and regulatory experience of groundwater in a few selected countries in the American continent so that relevant policy and management lessons can be drawn from these cases. The countries reviewed in this report are the United States of America (with the states of Texas, California, Oregon, and Florida), Mexico, Peru, Bolivia, and Chile. The report analyses, through a political, regulatory, and historical lens, the different groundwater regulatory tools, reflecting on the different laws, regulations, community actions, and institutional structures found in the different countries in order to curb groundwater over-abstraction.

Although this report does not attempt to be exhaustive as it is based on existing and accessible literature, it aims to go further than what has been presented until now and address the intrinsic challenges faced by current groundwater policies whilst offering a number of analytical and factual elements on groundwater governance presented in an original way. Semi-arid and arid countries are understandably more likely to (over)exploit their groundwater resources and the lessons drawn from the situation in other arid areas with different political economies, can potentially be very relevant for the MENA region as they may indicate potential solutions or – more often than not – flag the dangers or irrelevance of certain standardized, or seemingly desirable, policies. Thus, the examples presented here can provide a deeper understanding of the challenges countries in the MENA region face when it comes to reducing groundwater abstraction, echoing some of the attempts to regulate groundwater abstraction made by states in America.

The results and failures faced by governments and communities can also represent relevant insights when it comes to enforcing regulation or understanding legal barriers to policy implementation, all relevant and important lessons for other countries. Reflecting on a wealth of background stories and experiences will also provide a richer understanding and diversity of insights to these problems, what worked and did not work. The gravity and complexity of the situation require a systematic and wide-ranging approach building on existing knowledge and practices in and beyond the region, so that innovations in groundwater regulation and legislation can be found and the groundwater depletion trend averted.

Figure 1. Project case studies and cases reviewed for the project

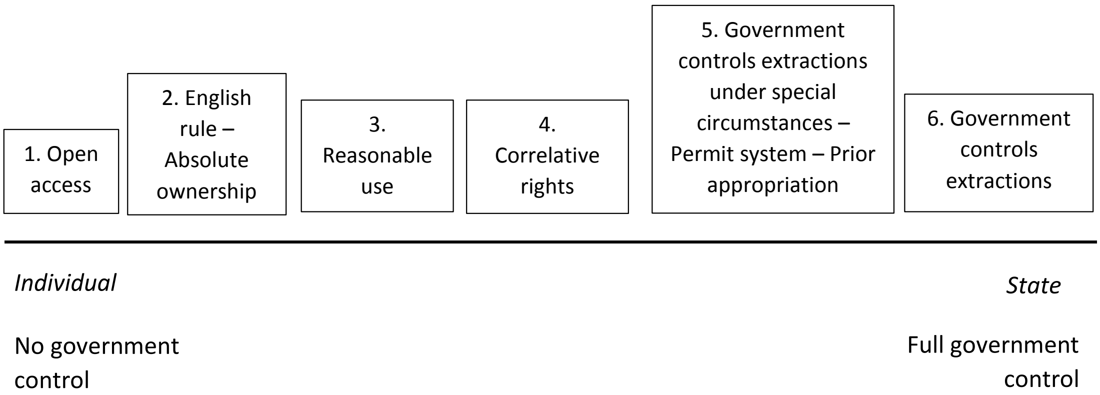


Section 1. Groundwater governance in the United States of America

Groundwater abstraction rights and management regimes in the USA

Smith (2003) has classified the different groundwater management regimes in the United States on a continuum based on the amount of government control exercised upon groundwater users. Smith's continuum (Figure 2) establishes the various possible groundwater management regimes as follows:

Figure 2. Smith's continuum of groundwater regulation regimes in the United States



Source: Adapted from Smith 2003.

Smith points out that the different legal systems of groundwater abstraction regulation in the United States fall somewhere between numbers two and four of this continuum. Number one on the continuum represents open access or no government regulation or control. Following the cases of 'pure' open access without any government control, the doctrine of '**Absolute ownership'** was established following English rule in 1843 and granted landowners unlimited rights to withdraw any groundwater found beneath the owner's land. All states using this legal regime (including Texas, see later) have adopted some kind of modification to this rule leading to a mixed system known as **'Reasonable use'** or 'correlative rights'. The doctrine of 'Reasonable use' states that a landowner's right to abstract groundwater beneath the property is limited to an amount needed for a reasonable or beneficial use on the land above.[1] The system of 'Reasonable use' allows groundwater users to abstract without liability for harm to adjoining landowners. The waste or transportation of water outside the limits of the property or further outside the limits of the basin (so called Restatement of torts rule) is also not allowed if it interferes with the right of use of adjacent owners.

A further development of the 'Reasonable use' doctrine limits the abstraction of groundwater by landowners by attributing individual shares of groundwater according to the landowner's land acreage. This doctrine, named the '**Correlative rights'** doctrine, maintains that the authority to allocate water is held by the courts with the power to sanction permits in the interest of public and private users sharing a single aquifer. California for instance uses a correlative rights system where groundwater pumping is 'apportioned pro rata' amongst

[1] Generally, any non-wasteful use of water for a purpose associated with the use of land from which groundwater is withdrawn is considered reasonable and conversely, any non-overlying use is unreasonable if it interferes with the use of water by overlying uses (Joshi 2005).

overlying landowners in times of shortage and often relies on piecemeal adjudications via courts to settle rights (Welles 2013).

The legal groundwater management regime called '**Prior appropriation'** provides that the first groundwater user has the right to maintain that use provided it is put to beneficial use and without waste and that these rights are superior to the rights of later appropriators (Smith 2003). Governments (usually local governments) will normally administer this right via permit procedures using a state official (Fink 2003).

The prior appropriation doctrine stemmed from the custom of miners in the American West developing their own water laws before any state or federal laws emerged. The essence of the prior appropriation law for the capture of water was: 'first come, first served'. Another mining rule which has also transpired to water law was the necessity for a miner to work a claim otherwise the right to the claim would be considered abandoned. This principle is known as 'due diligence' and also applied to the water needed to work a mining claim. If the miners abandoned the water, they abandoned the right. In Western states, the prior appropriation doctrine for water proved to be the more popular mechanism to regulate groundwater rights. This doctrine assigns water rights based on use and these rights are typically assigned through permits that designate the quantity of groundwater that may be withdrawn (Donohew 2012). In a case where groundwater availability is less than the permitted demand, senior water rights have priority over junior rights holders.

Fink (2003) provides a comparative analysis of groundwater legal management regimes used throughout the United States (Table 1 and Figure 3). In her study she characterizes states with centralized public administration systems, such as those managed with a permit system and states that follow absolute ownership doctrines or common law. She also notes that groundwater management in the United State is extremely diverse and also decentralized.

According to Fink (2003), the number of states under the Absolute ownership rule varies according to the sources. The only state however consistently listed as using the Absolute ownership rule is Texas. All states listed as using the Absolute ownership rule have modified it. Even Texas is not uniform and has a limited permit system in place for the Edwards Aquifer Authority and the Harris-Galveston Coastal Subsidence District.

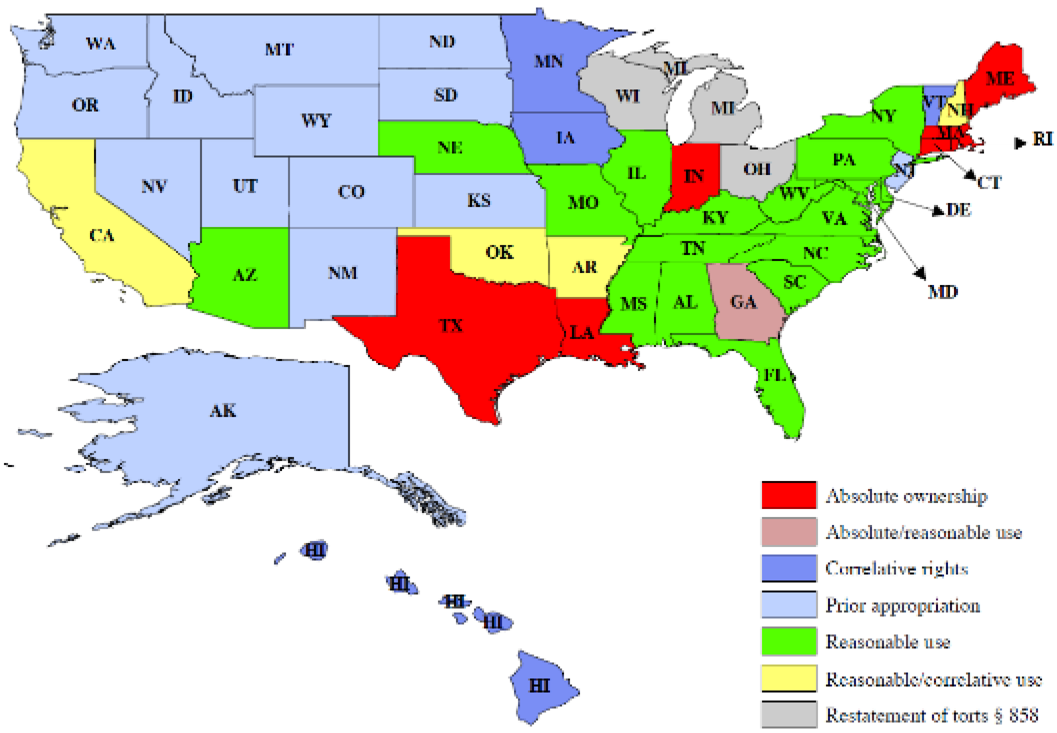
Hybrid water management systems have also appeared presenting a combination of various forms of rights such as riparian rights (for surface water) and prior appropriation rules for surface water and groundwater. Hybrid water management systems in the southwest of the United States have for instance incorporated another type of rule called 'pueblo water rights' (Fink 2003). These rights are found in the states of New Mexico, California, Texas, Arizona and Colorado and are based on claims going back to land grants existing before these states entered the union and descending from Spanish or Mexican mandates. The essence of this type of rights is that municipalities can use all the naturally occurring water needed for its residents within their boundaries and that they can also share water with its neighbours (Hutchins 2013). When in 1848 the Treaty of Guadalupe Hidalgo ceded these territories to the United States, it also confirmed traditional property rights including pueblo water rights extending to both surface and groundwater resources in those territories. When Los Angeles in 1899 needed to meet its growing water needs, it legally asserted pueblo water rights to abstract groundwater (Fink 2003; Hutchins 2013). Additionally, in 1975 the California Supreme Court confirmed the Los Angeles pueblo rights and initial claim to groundwater finding this right superior to all other overlying rights (Osuji et al. 2003).

Table 1. Groundwater legal management regimes in the United States

Legal management regime	*States*
Absolute ownership	Connecticut, Louisiana, Maine, Texas
Reasonable use and correlative rights	Correlative rights: California, Nebraska, Vermont Reasonable use: Alabama, Arkansas, Georgia, Illinois, Indiana, Missouri, New Hampshire, North Carolina, Pennsylvania, Rhode Island, Tennessee, Virginia, West Virginia Reasonable use – Restatement of torts: Michigan, Ohio, Wisconsin
Government controls – special circumstances – prior appropriation	Permit system: Massachusetts Permit system – correlative rights: Hawaii, Iowa, Minnesota Permit system – reasonable use: Arizona, Delaware, Florida, Kentucky, Maryland, Mississippi, New Jersey, New York, Oklahoma, South Carolina Permit system – prior appropriation: New Mexico, Oregon, South Dakota, Utah, Washington, Wyoming Prior appropriation: Alaska, Colorado, Idaho, Kansas, Montana, Nevada, North Dakota

Source: Fink 2003.

Figure 3. Groundwater rights in the United States



Source: Joshi 2005.

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Part 1. Groundwater governance in Texas

Acronym list

Bm3	Billion cubic meters
DFC	Desired Future Conditions
EAA	Edwards Aquifer Authority
GCD	Groundwater Conservation District
GMA	Groundwater Management Area
HB	House Bill
HPUWCD	High Plains Underground Water Conservation District
MAG	Modeled Available Groundwater
Mm3	Million cubic meters
PGMA	Priority Groundwater Management Area
SB	Senate Bill
TCEQ	Texas Commission on Environmental Quality
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
USD	United States Dollar

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1 Introduction

"Everything needs to change, so everything can stay the same"
(Giuseppe Tomasi di Lampedusa, The Leopard).

Groundwater demand in Texas is stretched between urban areas, agriculture and industry. Irrigation however continues to claim the largest share, using 79 percent of all groundwater in Texas, with 82 percent of this total drawn from the Ogallala Aquifer alone (Porter 2014). Groundwater use in Texas is also shifting, from rural areas with acquired private rights to expanding urban centers. The pressure of population growth and urban development on water resources in Texas represents a new and additional stress to natural resources, as cities naturally look for additional sources to supply water to their inhabitants. Urban areas do not hesitate to look for water outside its municipal boundaries, passing new regulations to expand their jurisdictional boundaries and lobbying to change state statutes to help remedy their water needs (ibid.). Additionally, shale gas extraction has increased groundwater consumption.

Over more than a century, the government, management, and regulation of groundwater have experienced several changes and yet, in essence, private property and local management remain at the core of groundwater politics and regulatory practice. As this report shows, throughout changes in legislation over the years, the institutional and governance framework of groundwater management in Texas has been bent and shaped, but these two elements have been maintained. The complexities and nuances of Texas groundwater regulatory system, arising from a long historical evolution of rules, laws, policies, are difficult to grasp, mirroring the vastness of its territory, the diversity of its landscapes and people. Following Texas geographical, social, and historical specificities, this part of the report introduces the structure and different layers of groundwater governance in this state, which results, in the end, in the picture of a complex, multi-faceted, and multi-layered system of governance.

By combining the study of policy systems, legal cases, management and regulation rules, with a practical and local focus, one of the main purposes of this section is the investigation of the continued tensions between local groundwater users and the necessity to establish common rules for the management and protection of groundwater resources. The constant friction following the push of central State agencies versus local communities, protective of their rights, represents one of the main drivers of policy and regulation vis-à-vis the management and control of groundwater in Texas. This push for more control and regulation by state agencies is met, many times antagonistically, by local communities pulling away from centralizing attempts from the state and trying to maintain their autonomy and rights.

The study also reviews different tools and regulatory norms used by Groundwater Conservation Districts (GCDs) to manage and control groundwater abstraction. This is done by introducing two different GCDs in Texas: the High Plains Water Conservation District and the Edwards Aquifer Authority. These are two special and also atypical GCDs as the High Plains Water Conservation District is the oldest and the largest, and it also operates within a powerful and large community of farmers in the Texas Panhandle region[2] overlying the largest aquifer in the United States, the Ogallala Aquifer. The Edwards Aquifer Authority is certainly unique in the state and the most complex groundwater management administration in Texas. It is also a

[2] The Texas Panhandle Region consists of the 26 northernmost counties in Texas, a rectangular area bordered by New Mexico to the west, Oklahoma to the north and east. This area is found in West Texas which, even though it geographically appears in the north of a map of Texas, is the vernacular term applied for this region.

hotspot for urban growth and habitat of endangered species at Comal and San Marcos Springs (hence the different disputes and conflicts regarding the allocation of water for urban uses). This makes it the most bureaucratic and potentially most administratively regulated groundwater management system in Texas, driven by the supply and demand of groundwater for urban use, the need to protect endangered species, and the pumping cap established by the Authority.

These GCDs reviewed in more detail could be considered exceptions and therefore not very emblematic of Texas's groundwater, given the fact that most GCDs remain small administrative units, with small budgets and limited staff. These two cases however, emphasize the variety and diversity of management and governance forms existing in Texas and exemplify how complex the governance, regulation, and management in these organizations can be. The study also looks at the institutional and regulatory fit within the state apparatus of the varied management and regulation practices developed by GCDs. This section adds detail and substance to this claim by showing the multiple layers of management and regulation of groundwater in Texas, and how they interact within a complex and poly-centric groundwater governance structure.

2 Groundwater and aquifers in Texas

The Texas Water Development Board recognizes 9 major aquifers in Texas and 21 minor aquifers, supplying 59 percent of all water uses in the State (2003 data) (Figure 4) (George et al. 2011). About 79 percent of this groundwater is used for irrigation (82 percent of which comes from the Ogallala Aquifer alone) (ibid.). Texas aquifers are heterogeneous in their geology, groundwater stored, and pumping rates. The Ogallala aquifer is practically a fossil aquifer whereas the Edwards Aquifer has a high recharge rate (Lesikar et al. 2002).[3]

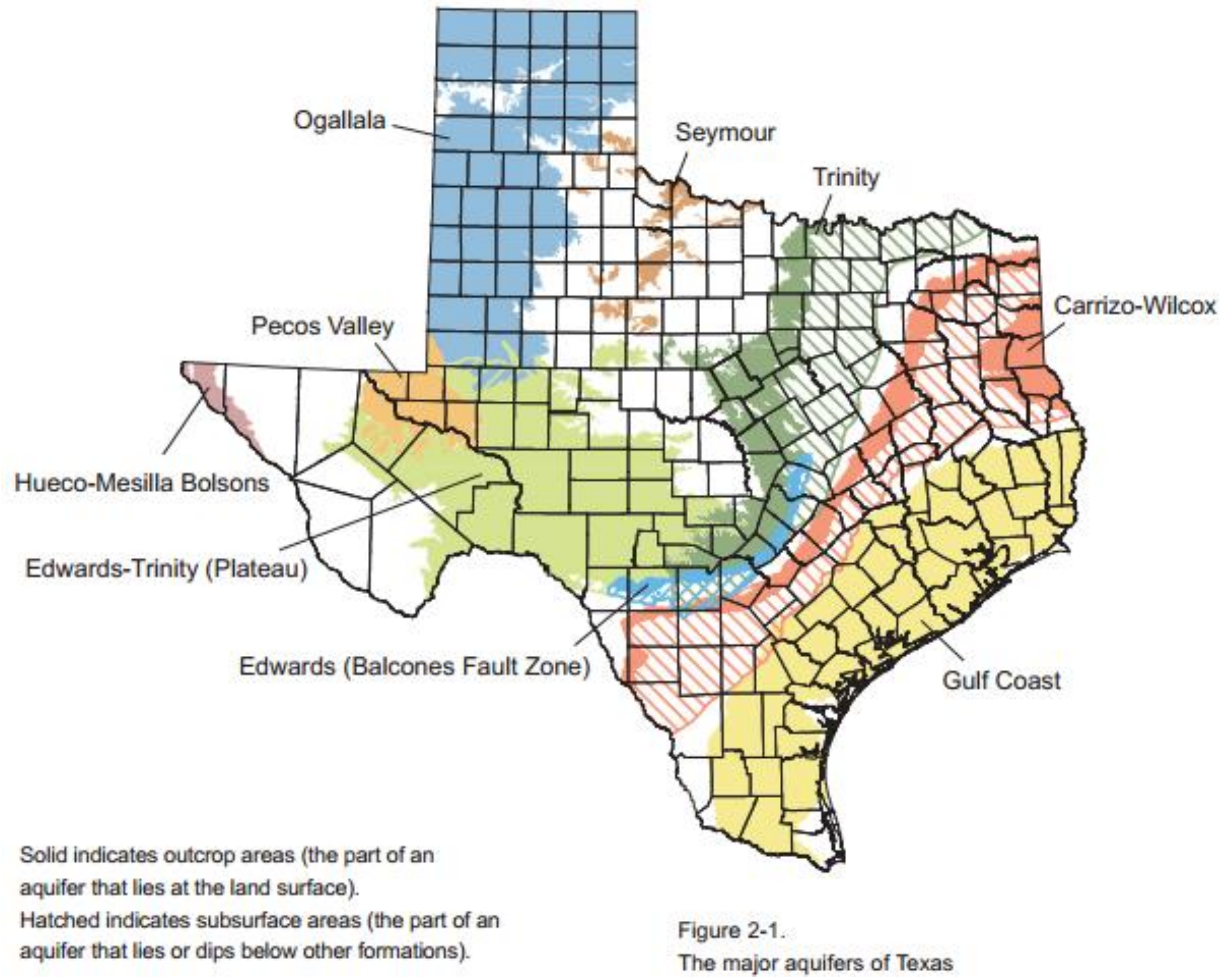
The Ogallala Aquifer is the largest aquifer in the USA and one of the largest in the world, covering more than 450,000 km2 across eight US states (Wyoming, South Dakota, Nebraska, Kansas, Colorado, New Mexico, Oklahoma, and Texas) (Sophocleous 2010). In Texas, the aquifer spans across the Panhandle region in the West.[4] The aquifer has a maximum thickness of 800 feet (243 meters) and freshwater saturated thickness averages 95 feet (30 meters) (ibid). Recharge for the Texan part of the Ogallala Aquifer has been quantified at 1.33 Bm3 per year and storage at 414 Bm3 (in 2007) (Scanlon et al. 2012). Depletion of groundwater was estimated at 2.98 Bm3 per year, giving this aquifer a lifespan of 139 years (ibid.).

Groundwater level declines in Texas range between 15 and more than 300 meters from pre-development years to 2000 (Figure 6). The largest areas of groundwater level depletion in Texas are the Trinity Aquifer with a decline of 800 feet (243 meters) and more. In the Ogallala Aquifer in West Texas, water levels have declined more than 200 feet (70 meters) (Figure 5) (Lesikar et al. 2002). The Edwards aquifer is one of the most productive aquifers in Texas. It is a karst carbonated aquifer covering an area of 2,314 square miles with a thickness ranging from 200 to 600 feet and freshwater saturated thickness averages 560 feet in the southern part of the aquifer (George et al. 2011).

[3] Estimates given by Lesikar et al. (2002) quantify the recharge rate for the Ogallala Aquifer in Texas at 0.30 million acre-feet and the Edwards Trinity at 0.78 million acre-feet per year.

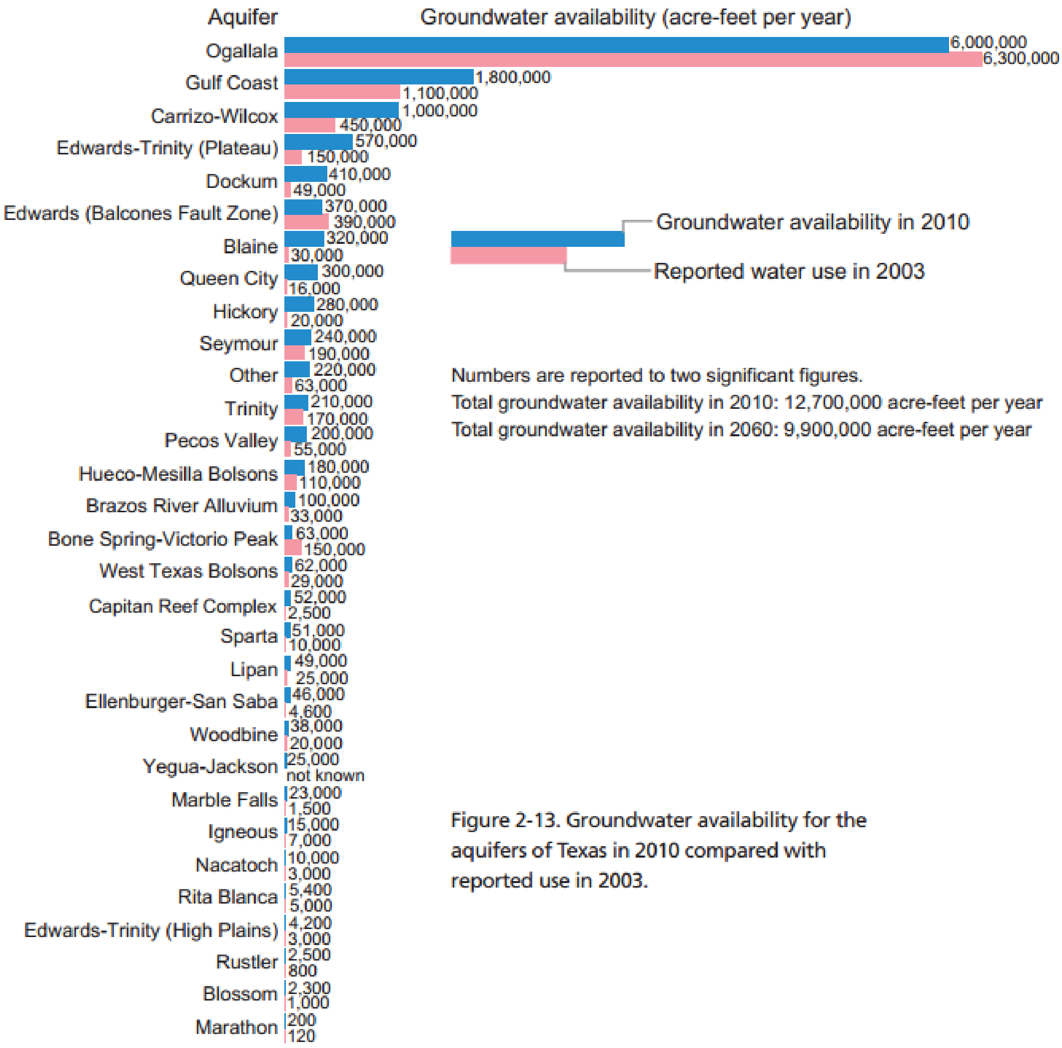
[4] As mentioned before, even though the Panhandle region of Texas where the Ogallala aquifer is located is geographically in the northernmost counties of a map of Texas, the vernacular term applied for this region is West Texas.

Figure 4. Major Aquifers in Texas



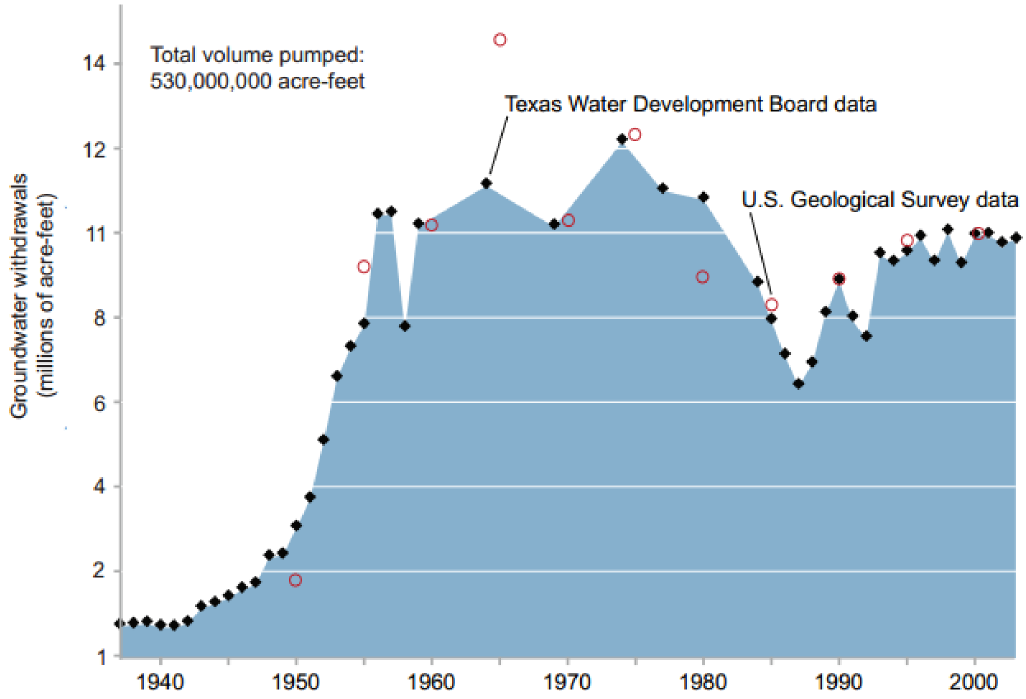
Source: George et al. 2011.

Figure 5. Groundwater availability in the aquifers of Texas in 2010 compared with reported use in 2003



Source: George et al. 2011.

Figure 6. Historical estimates of groundwater withdrawals in Texas (1935-2005)



Source: George et al. 2011.

3 Groundwater management legislation in Texas

3.1 From the rule of capture to the creation of GCDs in 1949

The adoption of the 'rule of capture' for groundwater in Texas in 1904 ensured the right of absolute ownership to landowners (Hutchison 2006).[5] This rule, which was enshrined by the Texas Supreme Court in 1904 in the landmark case of Houston Texas Central Railroad Company vs. W.A. East,[6] reflected the initial lack of understanding of groundwater and became the foundation of the most powerful legal precedent of Texas law regarding groundwater (Teel 2011).

As a result of severe droughts in 1910 and 1917, Texas voters approved an amendment to Texas constitution in 1917 acknowledging that the conservation of the state's natural resources was a public right and a state duty (Welles 2013). Although this amendment committed the state to a broad program of water conservation, Teel (2011) suggests that the amendment seemed a reactive course of action to empower the state with regulatory measures in periods of acute resource depletion, and was not a pre-emptive move in order to provide new regulatory tools to improve water management. Nevertheless, this amendment authorized the legislature to pass the appropriate laws to conserve and preserve natural resources, interpreted as a responsibility

[5] The doctrine of 'rule of capture or also called 'Absolute ownership' was established following English rule in 1843 and granted landowners unlimited rights to withdraw any groundwater found beneath the owner's land (Smith 2003). Under the 'rule of capture', no permit is required to drill and pump groundwater, as much groundwater as needed/desired can be pumped.

[6] In this landmark ruling, the Houston Texas Central Railroad Company dug a well on property it owned in Denison, Texas, in order to supply water for its locomotives and workshops. The well produced around 25,000 gallons of water per day, ultimately drying the plaintiff's domestic well which had been dug prior to the railroad's company well (Porter 2014).

of the state (Dupnik 2012). Most of these powers would however be later devolved to a new local organization created in 1949 to manage groundwater: the Groundwater Conservation District.

The need for groundwater management became in the following decades, the subject of much debate due to concerns about the excessive abstraction of groundwater from the Ogallala Aquifer. In 1934 the Texas Board of Water Engineers and the United States Geological Survey (USGS) produced a report that stated the need for a law to manage groundwater, by declaring groundwater property of the state, in order to guarantee the rights of those already making beneficial use and also to exercise proper control over future groundwater development (Dupnik 2012). Several draft bills were filled developing these principles, and advocating revocation of open-access regime, giving municipalities and manufacturers highest priority in accessing groundwater (Nachbaur 2014). Irrigation would be granted lowest priority and eventually permits would have been required for new irrigation wells. Such repeated attempts to subject groundwater to state rule polarized Texas into pro-regulation and anti-regulation supporters (Teel 2011). Urban centers and conservation associations supporting these measures were up against irrigation interests, who argued that any legislative measure attempting to govern groundwater would interfere with the rights granted by the Supreme Court of Texas (ibid.).

As a reaction to these legal attempts (in 1937, 1941, 1947, and 1949), the Texas Farm Bureau which represented the interests of the 'high plainsman' [7] prepared a counter bill creating local groundwater districts as a middle-ground option which reflected the reluctant view that, if there had to be regulation, it would have to be local. [8] Thus, the Groundwater Conservation District Act of 1949 was passed as a political compromise, initiating the approach to local groundwater management, followed until today in Texas, with no other reason than to avoid centralized control, granting counties the responsibility to initiate the creation of GCDs (Dupnik 2012).[9] At that time however, the concern over the exploitation of groundwater resources had already arisen amongst 'interested segments of the public', coinciding with a time when the Ogallala had already reached a critical level due to excessive pumping (Woodruff and Williams 1952). The Act was passed as a compromise based on locally controlled groundwater districts. It gave the irrigators the local control they wanted and the conservation and municipal interests a step towards conserving and regulating groundwater. The district groundwater bill was signed in 1949, creating the only organized approach to groundwater regulation in Texas (Teel 2011).

External disruptions have also affected the governance system of groundwater in Texas and drought mitigation has significantly driven the management plans of GCDS. The drought that

[7] In his thesis, Dupnik (2012: 5) refers to Green (1973) who, in his book Land of the Underground rain: Irrigation in the Texas High Plains (1910-1970), transcribes several quotes from some high plainsmen from Texas stating their opposition to groundwater regulation: "This proposition [of creating a water district] should be met with 30-30's [rifles] and its sponsors not only driven back to the City of Austin, but on south across the San Jacinto battlefield and into the Gulf of Mexico where they can get their fill of water"; "[…] I don't want any control by anybody but the landowner. That's like asking who you'd rather be hanged by. […]"; "All the water under my land belongs to me … nobody can tell me how to use it … if my neighbor wants to drill wells right next to me, that's all fine with me. If the wells go dry, we will all run out together. […]".

[8] As summoned by another quote by a local high plainsman used by Dupnik (2012: 6), "I favor no control, but if we must have it, let it be local".

[9] The High Plains Water Conservation and Users Association (HPWCUA), emerged in the Panhandle area of Texas with the objective to oppose any type of legislation attempting to control groundwater. This first association was mostly comprised of landowners and irrigators. The HPWCUA gained its initial momentum in 1948, when a bill by the Texas Water Conservation Association tried to remove groundwater private ownership rights and place them under the legal doctrine of correlative rights as well as prioritizing municipal rights to groundwater over irrigation needs.

lasted between 1950 and 1957 affected 244 of 254 counties in Texas (classified as disaster areas), and costed USD 3.5 billion for each year of drought (Wythe 2011).[10] The High Plains Underground Water Conservation district changed its regulations in 1954 and set up larger minimum distances between wells, and old wells could no longer be replaced with larger ones without obtaining a new permit from the district board. While some counties were however reluctant to join or form their own GCDs, the chairman of the Governor's committee on Water Conservation stated that the existing water management laws had been adopted on the theory of plenty, and that they would have to be reviewed to meet the existing situation of scarcity (Teel 2011). In the High Plains Underground Water Conservation District, the drought caused a drop in irrigated land from 3.33 million acres to 3.135 million acres between 1958 and 1969, with a parallel increase in drilled wells from 35,833 to 45,365. The district also saw a generalized drop in the water table, with more than 73 percent of irrigated acreage registering water table drops from less than a foot to eight feet per observation well (Teel 2011).

Also as a reaction to the 1950s drought, the Texas legislature created the Texas Water Development Board (TWDB) in 1957, with a constitutional amendment that authorized the Board to administer a Water Development Fund totaling $200 million to assist communities at the local level in order to develop and maintain water supplies. That same year also saw the passage of the Texas Water Planning Act, which created a Texas Resources Planning Division within the Board of Water Engineers.

3.2 The GCD as a management and regulatory unit

Following the 1949 Texas legislation, GCDs can be created following three different procedures:[11] 1) by action of the Texas Legislature (usually introduced by a Senator or Representative). A procedure will be established by the Legislature for its confirmation by the county and for the creation of a board, including all powers granted to GCDs following Chapter 36 of the Texas Water Code. Following Johnson (2013), many districts have recently excluded from these powers the exercise of eminent domain[12] and the assessment of ad valorem taxes. Over the last decades, the majority of GCDs have been established through the action of the Legislature (ibid.); 2) by landowners filing a petition with the Texas Commission on Environmental Quality (TCEQ);[13] 3) by the TCEQ on its own motion, with the limitation that this power only applies to areas within a priority groundwater management area, having failed through local action to create a GCD or integrate an existing one (ibid.).

The enabling legislation of a GCD allows them to choose to elect or appoint their boards of directors. Generally five to eleven directors representing different precincts within a county

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[10] Other assessments of the impact of the drought have calculated agricultural losses at 3 billion dollars state-wide (Teel 2011).

[11] GCDs were initially created by a petition to the Board of Engineers. Another procedure that leads to an inclusion of land into a GCD is the annexation of territory by an already existing GCD.

[12] The legal notion of 'eminent domain' indicates the power by the government to take private property for public use. The exercise of eminent domain is regulated by the Texas Water Code (Section 49.222), stating that districts or water supply corporations "may acquire by condemnation any land, easements, or other property inside or outside the district boundaries, or the boundaries of the certificated service area for a water supply corporation, necessary for water". This only applies to surface water however. With groundwater, according to Chapter 36 of the Water Code, the power of eminent domain by GCDs may not be used "for the condemnation of land for the purpose of: 1) acquiring rights to groundwater, surface or water rights; or 2) production, sale, or distribution of groundwater or surface water" (Section 36.105(b), Texas Water Code)."

[13] The TCEQ must find "that the boundaries of the proposed groundwater conservation district provide for effective management of the groundwater resources and determine whether the proposed groundwater conservation district can be adequately funded to carry out its purposes" (Johnson 2013: 114).

serve four-year terms. Not only are Districts created locally but they are also funded and managed locally. Districts can either be funded by an ad valorem tax that increases local property taxes to finance operations and staff and/or fees for issuing permits or registering new wells. GCDs also issue fines for wells where the construction or operations fall outside of regulatory scope. Permits for wells producing more than a specified amount and that minimum amount are issued by GCDs, and vary depending on the District. Moreover, Districts cannot deny permits for wells pumping less than the designated amount required to obtain a permit (Teel 2011).

The present-day purpose of the GCDs is to maintain individual landowner rights to groundwater (the rule of capture), which, at the same time, is the reason for their limited powers. As Dupnik (2012) wrote, groundwater property is deeply ingrained in the concept of land and private property, outside the scope and reach of the state. The initial prerogative for the establishment of GCDs was to act as a mechanism to protect the large majority of Texas (rural at the time, with very low densities) from being driven by market and population demands. This move left the state outside groundwater management, making more difficult a state-wide system of groundwater conservation. More recent attempts by the state to further regulate groundwater abstraction have created frictions with this system of local groundwater management, ingrained within a particular ethos of individual rights and devolved powers. This conflict could have the potential to undermine further attempts to increase regulation and enforcement capacities by the state.[14]

The 1980s saw the establishment of nineteen new GCDs. These Districts did not coincide with the natural geological boundaries of aquifers and followed mainly administrative boundaries between counties. Although this trend conflicted with the original purpose of GCDs, the significance of county-level groundwater management in Texas is due, according to Dupnik (2012), to the strong belief in private property rights, a general aversion to outsider interference (whether state or federal), the related desire to preserve local autonomy and the prevention of groundwater export outside the area of origin. Counties became the political and administrative unit devoted to groundwater management after their approval by county commissioners' courts (for single-county districts) or the appropriate state agency for multi-county districts.

3.3 Groundwater management in the 1990s and 2000s: the consolidation of GCDs

The fact that most GCDs follow county-based jurisdictions, a pattern that evolved since the mid-1990s, created a proliferation of small-scale GCDs with political boundaries (58 percent of the

[14] The lack of enforcement of groundwater management rules at the local level is hard to assess. However, the example of the Texas Railroad Commission can be used in order to illustrate the lack of enforcement and monitoring of water quality rules in the oil and gas sectors. This is relevant to groundwater as even though the TCEQ is in charge of issuing letters for the total depth of surface casing needed to protect groundwater from drilling and disposal activities associated with oil and gas exploration, development, and production (Sunset Advisory Commission 2011a), it is the Railroad Commission who oversees the enforcement of the rules. As the Sunset Advisory Commission (2011b: 33)) wrote, monitoring is expensive "and inspectors cannot reasonably oversee the significant amount of oil and gas activity in a state the size of Texas". Even if the Railroad Commission could "go to great lengths to ensure compliance through monitoring and inspections", "the Commission takes relatively few enforcement actions, resulting in a lack of deterrence for future noncompliance." In the Sunset Advisory Commission assessment of the Railroad Commission, it was found that of all 80,000 oil and gas production-related violations found in 2009, "field staff forwarded less than 4 percent to the agency's central office for enforcement action" (ibid.). For water pollution, the Sunset Advisory Commission found that more than 18,000 water protection violations had been committed but the Railroad Commission only took enforcement action on less than 1 percent of these violations" (ibid.). Also, "the Commission is unable to say with certainty that there were no serious violations in the roughly 17,900 water pollution violations that did not go for enforcement, since the Commission relies on the discretion of each district office to determine which violations should be forwarded for enforcement action" (ibid.). Of those 18,000 violations, only 150 resulted in an enforcement action (ibid.).

98 confirmed GCDS encompass a single county or less). This translates into a strong influence of county governments and politics over the running and development activities of the GCDs, as initial criticism of the localized control and limited authority of GCDs pointed out (Kaiser and Phillips 1998).[15] The creation process of GCDs can be in itself subject to political alliances. As it was defined by the 1949 Groundwater Conservation Act, the creation of a GCD has to respond to a local petition and a decision by the local county commissioners court[16] that the formation of the district is 'feasible and practical', followed by a majority vote by local residents. Although the petition process has changed and this is one of three ways to create a GCD (Johnson 2013), this precedent for substantial county involvement was maintained and statutorily incorporated into what is now the Priority Groundwater Management Area (PGMA). Following these rules, county commissioners have the power to appoint a steering committee to begin the process of informing local residents on the GCD creation process, they can also request the annexation of the entire county by an adjacent GCD within a proposed PGMA (Dupnik 2012).[17]

The creation of GCDs following county lines rather than hydro-geological limits increases the hydrological disconnect of such organizations and the potential problems of fit. The size of these districts also brings the issue of economies of scale and problem of insufficient funding and areal extent as these GCDs can have limited revenue and operational efficiency due to their insufficient jurisdictional area. Funding via taxes and fees is also a hindrance for the GCDs have taxing authority, as many local communities do not want to hear about raising taxes and therefore districts have to compromise with a rate that provides limited funding within an often hostile environment opposed to further taxes (Mean tax rate is 0.060 USD per 100 USD of land valuation for groundwater users, much less than the statutory cap of 0.5 USD /100 USD) (Dupnik 2012).[18]

The 1990s saw an increase in the creation of GCDs as well as legislative efforts. The Texas Senate Bill 1 passed in 1997, right after a drought in 1995-1996 (Wythe 2011), recognizing the importance of groundwater not only for agriculture but also for individuals, cities, counties and industries. This senate bill also granted more regulatory powers to the districts by allowing requirements for groundwater abstraction permits (such as requiring permits for wells abstracting more than 25,000 gallons per day) (95 m3) and by statutorily designating GCDs as

[15] Following Woodruff and Williams (1952 in Kaiser and Phillips 1998: 422), referring to the 1949 GCD legislation, "the act falls short of being a complete independent groundwater code – it is merely a short appendage to the lengthy chapter on Water Control and Improvement Districts."

[16] The local county commissioners' court is the governing body of county government in Texas. This court has five members, the country judge and four commissioners. They exercise legislative functions and have limited judicial powers. Courts are the administrative heads of the county government structure. The court combines elements of judicial, legislative, and executive functions, it adopts the county's tax rate and the budget (Local Government Code, Title 3 – Organization of County Government, Subtitle B – Commissioners Court and County Officers, Chapter 81 – Commissioners Court, Subchapter A – Organization and Procedure, http://www.statutes.legis.state.tx.us/Docs/LG/htm/LG.81.htm, Accessed 25th January 2016).

[17] A PGMA (Priority Groundwater Management Area) is, according to the Texas Commission on Environmental Quality, "an area designated and delineated by TCEQ that is experiencing, or is expected to experience, within 50 years, critical groundwater problems, including shortages of surface water or groundwater, land subsidence resulting from groundwater withdrawal, and contamination of groundwater supplies. […]If a study area is designated as a PGMA, TCEQ will make a specific recommendation on groundwater conservation district creation. State law authorizes the citizens in the PGMA two years to establish a Groundwater Conservation District (GCD). However, if local action is not taken in this time-frame, the TCEQ is required to establish a GCD that is consistent with the original recommendation. Under either scenario, the resultant groundwater conservation district would be governed by a locally elected board of directors" (http://www.tceq.state.tx.us/groundwater/pgma.html, Accessed 25th January 2016).

[18] In order to have taxing authority, a GCD has to hold a local election on the matter and have enabling legislation that does not exclude the possibility. Many GCDS, such as Hays-Trinity GCD for example, do not have the tax base and therefore survive off of a very small budget and with limited staff.

the state's preferred method of groundwater management (Teel 2011). It also clarified and increased the authority of GCDs (allowing GCDs to impose more restrictive conditions for new permits and strengthening well spacing regulation) (Dupnik 2012).

This Senate bill also provided technical support to the GCDs by the Texas Natural Resource Conservation Commission and the Texas Water Development Board. With this increased support, however, more accountability was demanded from the districts as they were required to provide more comprehensive management plans in conjunction with regional water management plans. Districts also became subject to audits on management performance reviews, in order to assess whether they were meeting their planning objectives. Senate Bill 1 also bolstered legal provisions for designating critical areas, terming them Priority Groundwater Management Areas (PGMA).[19]

In 2001, Senate Bill 2 included the establishment of sixteen regional Groundwater Management Areas (GMAs), all composed of GCDs and serving as an administrative and managerial base for future state water management plans (Teel 2011).[20] The Texas Commission on Environmental Quality along with the Texas Water Development Board reviewed the status of the aquifers and 16 GMAs across the State to determine if these areas were in need of immediate management. If so, these areas are designated as PGMAs. Up until 2013, 8 PGMAs have been designated. The Legislature authorized the Texas Commission on Environmental Quality (TCEQ), the Texas Water Development Board (TWDB), and the Texas Parks and Wildlife Department (TPWD) to study, identify, and delineate PGMAs. The area to be designated has to experience, or be expected to experience within 50 years, critical groundwater problems such as shortages of surface water or groundwater, land subsidence resulting from withdrawal of groundwater, or contamination of groundwater. If a study area is designated as a PGMA, the TCEQ will make the recommendation to create a specific GCD (if there is none). State law grants a period of two years for the citizens of the PGMA to create it but if they fail or if local action is not taken, then the TCEQ is required to establish one.[21]

In 1999, the *Sipriano* court ruling[22] precipitated the creation of more GCDs when it highlighted the need for groundwater management and pointed to the legislative duty and responsibility of the state to do so under the Conservation amendment (during that 76th legislative session, 30 GCDs were considered for creation against 44 GCDs created during the previous 50 years). This court ruling also coincided with another dry period in Texas' climatic history (the 1999-2002 drought).[23] The legislature eventually reached the compromise to create 13 new GCDs with

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[19] This had happened first in 1985 but under a different name (TWDB 2016, pers. com.).

[20] The GMA process goes back to the earliest days of GCDs in the 1949 legislation (TWDB 2016, pers.com.). The legislature at the time had authorized petitions to designate "'underground water reservoirs', the predecessor to groundwater management areas, by the Texas Board of Water Engineers" (Mace et al. 2008: 1).

[21] https://www.tceq.texas.gov/groundwater/pgma.html/#whatis (Accessed 2nd March 2014).

[22] The Sipriano Court ruling by the Texas Supreme Court questioned for the first time in 90 years whether the state should adhere to the common-law rule of capture or abandon it for the rule of reasonable use. Although the Supreme Court ruled in favour of the defendants by upholding the rule of capture, the reflections by the Court on groundwater management were at least symbolic as the court blamed the same rule of capture for the lack of groundwater management in Texas. The Court however deferred the decision to maintain or reform the rule of capture to the Legislature (Supreme Court of Texas, Bart SIPRIANO, Harold Fain, and Doris Fain, Petitioners, v. GREAT SPRING WATERS OF AMERICA, INC. a/k/a Ozarka Natural Spring Water Co. a/k/a Ozarka Spring Water Co. a/k/a Ozarka, Respondents, No.98-0247, http://scholar.google.com/scholar_case?case=2359593130051980541&hl=en&as_sdt=2&as_vis=1&oi=scholarr, accessed 24th March 2014).

[23] During this drought, the Rio Grande stopped flowing into the Mexican Gulf, and crops were lost in the South Plains. The drought also resulted in 16 casualties in 1999 and 32 in 2000 due to heat. Henry, T. 2011 "A history of drought and extreme

limited regulatory authority (8 of which single county), expected to be dissolved if not ratified by the 77th Legislature in 2001, or if ratified accepting broader powers and authority to prepare management plans (Dupnik 2012). Another reason for this deferral, according to Teel (2011), was the need to synchronize the creation of new groundwater districts with existing regional and state water plans. The approval of the new GCDs was deferred until 2002 so that they could work within the new regional planning limits of the new 2002 Texas Water Plan.

The 2002 Texas Water Plan then became a way to unify even more the administrative and managerial boundaries between different GCDs by following the boundaries of the major aquifers in Texas (TCEQ 2011). During the 1990s, the creation of groundwater districts had followed political boundaries rather than hydrogeological. The sixteen Groundwater Management Areas forced the districts to work closely together and also placed them under management support of the Texas Water Development Board. For Teel (2011), what is relevant about this process is that conservation districts that began as a way to circumvent and obstruct the state's centralized authority seemed to be finding a new purpose within a state-wide plan to regulate and manage groundwater.

By 2000 Texas had forty seven groundwater conservation districts, serving as a vehicle to implement state-wide water management plans whilst pacifying users' demands for sustained local governance. The creation of new GCDs did not however always find adepts amongst local community members. For example, some of the residents and groundwater users of Brazos Valley Groundwater Conservation District, effective in September 2001, were not accustomed to limitations on the amount of water they could pump and they expressed fears that the newly created district would strip landowners of their private rights. The fact that the pumping of groundwater would be subject to restrictions presented for some landowners a conflict with their private property rights (Teel 2011).[24],[25]

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weather in Texas", November 29, 2011, http://stateimpact.npr.org/texas/2011/11/29/a-history-of-drought-and-extreme-weather-in-texas/ (Accessed 6th July 2015).

[24] When the Brazos Valley Groundwater Conservation District was approved in 2002 as a permanent regulatory agency for groundwater, the district began to register and issue groundwater abstraction permits. Wells used for domestic purposes, abstracting less than 189 cubic meters of water per day, were required to be registered, but exempt from obtaining a permit. The district did not charge fees for registration, only for issuing permits. The district also issued standard requirements for new wells being drilled that would only require registration (installation of casing pipe and fittings to prevent groundwater waste). New wells that required a permit needed approval by the majority of the members of the groundwater conservation district. Wells already in use and abstracting more than 189 cubic meters of water per day were granted 'historic use permits' based on the highest annual amount of water to be withdrawn from an active well for beneficial use (Teel 2011). The possibility that groundwater conservation districts would take away landowners private rights was fought against by the Texas' Landowner's Council, a state-wide organization. They argued in the case of the Brazos Valley, that the groundwater conservation district infringed on private property rights and wanted to establish groundwater rights on a per-acre basis, thus allowing landowners to abstract water in proportion to the amount of land owned. The Texas' Landowner Council also criticized the democratic voting process used in the groundwater conservation district as it undermined landowner and irrigation interests, for it allowed a larger majority of non-landowning citizens to prevail over a minority of landowning members (Teel 2011).

[25] As mentioned by Teel (2011), during one of the meetings in July 2002, held before the creation of the groundwater conservation district, Representative Lois Kolkhorst, member of the Texas House of Representatives from Brenham, Washington County (on the southern border of Brazos County), urged the creation of the groundwater conservation district, stating that it was needed in order to impede water marketers from removing water from the valley. The rules of the Brazos County Groundwater Conservation District contemplate the 'transfer of groundwater out of the district' and refers to the transportation of bulk groundwater between users. According to the Brazos Valley Groundwater Conservation District Rules, groundwater produced from a well within the district may not be transported outside the boundaries without having obtained a permit from the Board. This permit must be obtained on top of the drilling permit. A series of reports and complementary information about the effects of the proposed transfer on local groundwater resources will have to be submitted to the Board (Rule 10.3 and Rule 10.4). The Board will not deny a transport permit based on the fact that the applicant seeks to transport groundwater outside the district. The district may not impose more restrictive permit

The *Sipriano* court ruling also opened the door, according to Dupnik (2012), for future litigation as disgruntled landowners affected by GCDs regulatory decisions can sue the district in court. As court cases can be lengthy and expensive, GCDs can be inclined to agree directly with users or "to err on the side of caution and relax regulations or even avoid implementing sustainable resource management policies, in order to avoid a protracted legal defense" (Dupnik 2012: 48). In broader terms, the reason for this type of behavior in Texas is, according to Somma (1997), ideological and driven by a strong reaction to state control. Based on the experience in Arizona, where the 1980 groundwater law controls groundwater use quite strictly, West Texans refer to it as an example of the price to pay for failing to organize locally (ibid.). This ideological resistance is however productive as it drove farmers in Texas to counteract the state role by improving self-governance mechanisms (i.e. conservation districts) ruled almost entirely by local interests. Based on this structure, groundwater policy in West Texas moves in tandem with local management relying on professional norms and organizational commitment from users (ibid.). Further changes in Texas water law increased the powers of GCDs adding more funds and capacities.

3.4 Further legislation in 2005 and after

Amidst another drought (2005-2006), causing state-wide losses of USD 4.1 billion,[26] in 2005 the Senate of Texas passed House Bill 1763 which represented a 'profound change' in how groundwater availability is determined in Texas (Mace et al. 2008: 1). This Bill represented the regionalization of decisions on groundwater availability, as well as required the definition of permitting targets and caps for groundwater abstraction, which ultimately affect the rules and plans of individual water districts.

The Texas Water Code from 2005 further codified and legislated the management of groundwater resources in the state.[27] The Code from 2005 maintained previous Chapters from earlier versions. Chapter 36 of the Code for instance granted powers to the districts in order to fulfill their role of "conservation, preservation, protection, recharging, and prevention of waste of groundwater, and of groundwater reservoirs or their subdivisions, and to control subsidence caused by withdrawal of water from those groundwater reservoirs or their subdivisions".[28] The legislators had included provisions such as well spacing; enforcement of rules by injunction or other remedy in a court; creation of inventories of groundwater wells; purchase, sale, distribution and transportation of surface and groundwater; completion of research projects and collection of data; creation of rules and permits for the transfer of groundwater outside district limits; levy annual taxes to pay district expenses; setting fees for administrative services;

conditions on transporters than the district's limitations already imposed on existing in-district users, unless the district is dealing with new operating permit applications and permit amendments to increase use by historic users, and the limitations are reasonably necessary to protect existing use (Rule 10.4 of the Brazos Valley Groundwater Conservation District).

[26] Henry, T. 2011 "A history of drought and extreme weather in Texas", November 29, 2011, http://stateimpact.npr.org/texas/2011/11/29/a-history-of-drought-and-extreme-weather-in-texas/ (Accessed 6th July 2015).

[27] The specific statutory laws regarding the regulation of groundwater management in Texas are Chapters 35 and 36 of the Texas Water Code which rely on the Conservation Amendment to the Texas Constitution of 1917. Chapter 35 covers Groundwater Management Areas and Chapter 36 addresses Groundwater Conservation Districts, the "preferred method of groundwater management in Texas", and defines the authority and regulatory powers of Groundwater Conservation Districts (Hutchison 2006).

[28] Texas Water Code, Section 36.0015.

development of management plans (Teel 2011).[29] Thus, a conservation district's mandate under the Texas Water Code extends to them the obligation to determine groundwater extraction levels (further elaborated as 'Desired Future Conditions' in House Bill 1763, see below). Without a conservation district however, landowners have the legal ability to pump as much groundwater as it pleases them.

Texas House Bill 1763 in 2005 also represented a compromise in view of the lack of success and rejection by the House of Representatives of a proposed Senate Bill 3 (2005) which would have increased regional groundwater planning provisions ensuring consistent groundwater management for GCDs, establishing special Groundwater Management Area Councils with increased integrating powers to adopt and supervise desired future conditions and groundwater availability estimates (Teel 2011). These changes did not make it into the 2005 Bill.

The purpose of Groundwater Management Areas (GMAs) is to do joint planning. Since 2001, the responsibility to create GMAs was granted by the Legislature to the Texas Water Development Board (TWDB) which directed it to delineate GMAs for all major and minor aquifers in Texas (Mace et al. 2008).[30] The 2001 Senate Bill 2 had required that GCDs share their groundwater management plans with each other within the GMA. Later in 2005, House Bill 1763 specifically required joint planning amongst GCDs and collectively establish the 'Desired Future Conditions' (DFCs), i.e. what aquifer conditions would be maintained within a future planning time frame, and used to calculate 'managed available groundwater values' in the future (Mace et al. 2008) (see following section). Before this Bill, each GCD defined its own groundwater availability which was then included in the district's management plans. With the established DFC for each district submitted to the TWDB, the Board estimates the 'managed available groundwater' to the districts "for inclusion in their groundwater management plans and to the regional water planning groups for inclusion in their regional water plans" (Mace et al. 2008: 3).[31]

Regional Water Planning Areas function through bylaws adopted to manage and develop planning functions for water resources through designated political subdivisions of the state to administer its planning process (e.g. a river authority). Amongst other tasks, the regional water planning process consists of quantifying current and project water demand over a specific planning horizon (in this case 50 years as the horizon of the TWDB), evaluating and quantifying current water supplies, evaluating water management strategies and their impacts on water quality, recommending regulatory, administrative and legislative changes, and ensuring the required level of public participation in the adoption of the plan.[32] Once the planning group has issued its regional water plan, it is sent to the Texas Water Development Board for approval.

House Bill 1763 salvaged the regional approach to groundwater management, according to Mace et al. (2008), but made it a joint process requiring the collaboration of the GCDs belonging to a particular GMA.[33] House Bill 1763 also aimed at regulating well permits in order to control

[29] These are specifically detailed in the Texas Water Code, Sections 107 (Research and management plans), 112 (Drillers' logs), 113 (Permits for wells), 114 (Permit amendments), 115 (Drilling or altering wells without permits), 116 (Regulation of spacing and production), 118 (Open or uncovered wells), 205 (Authority to set fees).

[30] Groundwater management areas existed in Texas since 1949 (designated as 'underground water reservoirs') and had been established by the Texas Board of Water Engineers in order to create groundwater conservation districts. In 1985 the Texan Legislature change the name to 'management areas' and then in 1989 to 'underground water management areas'. The final name of 'groundwater management areas' was given in 1995 (Mace et al. 2008).

[31] See following section for a more detailed analysis of the DFCs.

[32] Regional Water planning in Texas, http://www.twdb.state.tx.us/publications/shells/RegionalWaterPlanning.pdf (Accessed 17th March 2014).

[33] These issues will be studied in further detail in the following section on DFCs.

groundwater abstraction, a consequence of the establishment of DFCs. Before the Bill the majority of districts did not have in place an overall cap on groundwater abstraction. With the bill, GCDs "shall issue permits up to the point that the total volume of groundwater permitted equals the managed available groundwater" (Mace et al. 2008: 3).

In 2011, however, Senate Bill 660 reinforced even more the local role of GCDs by making GCD representatives the sole voting members of GMAs and also having a member representative in the Regional Water Planning Groups, a representational body that puts together regional analysis with a list of Water Management Strategies eligible for funding by the TWDB. According to Dupnik (2012: 802), SB 660 relegated GMAs to mere "lines on a map", facing the increasing importance of local management by GCD.

An important sentence by the Texas Supreme Court in 2012 ruled for the first time the precise nature of groundwater ownership, equating it to that of oil and gas (Edwards Aquifer Authority vs. Day). It has been argued that it would establish how far conservation districts can modify and regulate open access rule (Nachbaur 2014).[34] The case arose as two applicants submitted a demand to the Edwards Aquifer Authority for the right to pump 700 acre-feet of water per year claiming historical pumping rights[35]. The authority granted the farmers an allocation of 14 acre-feet per year based on the fact that their claim to historical rights did not prove that withdrawals from the well used during the historical period were placed to a beneficial use (Texas Supreme Court 2012). After the claimants sued the Authority under the argument that this low allocation needed compensation as part of their constitutional property rights, the Texas Supreme Court in its ruling held that groundwater users have an absolute vested property right to groundwater just like oil and gas and that 'landowners do have a constitutionally compensable interest in groundwater' (Texas Supreme Court 2012). Thus, this ruling created the legal precedent in Texas that landowners could argue the case that GCDs could compensate them for denying or limiting pumping.[36],[37]

During the 84th Texas Legislature (in 2015), Senate Bill 1101 addressed regional water plans, defining the process of inclusion in the Regional Water Planning Group for those areas in Texas

[34] This however requires further legislation and judicial clarification (TWDB 2016, pers. com.). The EAA vs. Day ruling in 2012 decided that landowners have real property interests in groundwater under the land they own analogous to the landowners' property interests in oil and gas. The Court ruling also affirmed the right of the landowners to "assert a regulatory-takings claim against a Texas groundwater conservation district if it regulates groundwater withdrawals in a way that denies the landowner all economically beneficial use of his property" (Torres 2012: 144). Additionally, for Torres (2012: 144-145), the court ruling has "sown confusion about the capacity of the state [i.e. GCD] to regulate natural resources, while ignoring the science that ought to drive policy decisions".

[35] These are defined according to the Edwards Aquifer Authority rules: Paragraph 1.16(a) "An existing user may apply for an initial regular permit by filing a declaration of historical use of underground water withdrawn from the aquifer during the historical period from June 1, 1972, through May 31, 1993." Moreover, the rules continue by stating in Paragraph 1.16(e) "To the extent water is available for permitting, the board shall issue the existing user a permit for withdrawal of an amount of water equal to the user’s maximum beneficial use of water without waste during any one calendar year of the historical period. If a water user does not have historical use for a full year, then the authority shall issue a permit for withdrawal based on an amount of water that would normally be beneficially used without waste for the intended purpose for a calendar year" (Texas Supreme Court 2012).

[36] The Texas Observer, 'Come and Take it: court ruling dares regulators to limit pumping', September 3, 2013, http://www.texasobserver.org/texas-court-upholds-takings-claim-landmark-water-case/ (Accessed 2nd March 2014).

[37] In 2013, the San Antonio Fourth Court of Appeal used for the first time the legal precedent of 'Edward Aquifer Authority vs. Day' to rule that the Edwards Aquifer Authority owed landowners money for limiting their pumping rights. This represented an infringement of the claimants to their property rights over groundwater, defined as 'the unlimited use of water to irrigate a commercial-grade pecan orchard, and that property should be valued with reference to the value of the commercial-grade pecan orchards". The amount calculated to be paid to the owners of the orchard was established at USD 134,918.40 calculated as the market value price per acre for a dry land farm, and the market price per acre for irrigated farm land (Fourth Court of Appeals San Antonio Texas 2013).

not protected by a GCD (only one region, Region D, meets this requirement). The Bill established that the Regional Planning Group can determine the supply of groundwater for regional planning purposes in areas without a GCD (the supply will have to be compatible with the DFCs for the relevant aquifers in the GMA regulated by groundwater conservation districts). This Bill therefore goes towards closing the loophole in counties not managed by GCDs and extending the protection granted by the DFCs to these areas.

3.5 The Desired Future Conditions for groundwater in Texas

3.5.1 Setting up the DFCs

GCDs are currently in the process of setting up their second round of Desired Future Conditions (DFCs) in each designated Groundwater Management Area. For many GCDs this is a costly and time consuming process. GCDs put forward a proposal for their DFCs to their respective GMAs. The DFCs are voted via a two-thirds majority of GCDs. The DFCs have to come from the GMA, preventing the submission of DFCs that "do not work together hydraulically" (TWDB 2016, pers. com.). GCDs voting on Desired Future Conditions need to take into consideration specific requirements by the TWDB as specified in statute. The DFCs have to be "physically possible, individually and collectively, if different desired future conditions are stated for different geographic areas overlying an aquifer or subdivision of an aquifer within the groundwater management area" (Mace et al. 2008: 4). In the end, the GCDs "may not get exactly what they want (although I can't think of a case where there has not been consensus on the final DFCs – testament to the GCDs working together toward a unified goal within their GMA)" (ibid.). The consolidation of DFCs at the GMA level is done through iterations, the GCDs bring their preferences regarding the DFCs. Once groundwater availability is assessed through modeling (see below), GCDs make adjustments "to the pumping that results in the DFC to achieve consensus" (ibid.).

The allocated volumes within each DFC can also differ for each county (see Section 7.3.1). Even though rules are different, these DFCs have to be physically possible (TWDB 2015, pers. com.). With this system however, it is difficult to avoid 'pumping crossflow' in cases where there is aquifer interconnection between different GCDs. In these cases, GCDs voting for a certain DFC in the GMA can outvote a GCD against it. The GCD will then have to "to manage to the adopted DFC, even if they don't like it" (TWDB 2016, pers. com.). When DFCs are submitted to the TWDB for review, the board will determine if a DFC is physically possible and if is not it will be rejected,[38] but will not be able to "mandate the districts or GMAs to make the changes" (Porter 2014: 85; TWDB 2016, pers.com.). The DFCs may also be revised at any time but must be updated at least every five years. The public has also the right to appeal the GMAs' decisions and such right has been used several times across the state.

When setting aquifer pumping limits for their respective DFCs, GCDs choose in general "DFCs that allow current levels of pumping or even larger amounts. If a GCD has to curtail, it varies by district how they reduce pumping. Some districts have plans to reduce everyone proportionally. Others create study zones to look at the issue more closely before restricting pumping. In general, GCDs try to avoid curtailment to stay out of lawsuits; however, DFCs that result in reduced pumping are adopted" (TWDB 2016, pers. com.). Volumetric management is not used widely across Texas and at the GCD level compliance measures for DFCs can vary, be it

[38] So far this has not happened (TWDB 2016, pers. com.).

remaining volume in aquifer, aquifer drawdown, spring flows, or reduced pumping levels.[39] Depending on the voted measures to achieve the DFCs, volumetric control does not happen right away, "if the DFC is no more than 10 feet of drawdown in 10 years, the GCD may be simply measuring drawdown to see if they have a problem and then move into reductions/solutions once they realize there is a problem" (ibid.). Still, the GCDs' "exact abilities to constrain groundwater pumping subject to clarifications via the courts" (ibid.).

The 82nd legislature (in 2011) added to Chapter 36 of the Water Code in SB 660, nine factors to be considered as part of the DFCs issued by the GCDs. These include; "1) aquifers uses of conditions within the management area, including conditions that differ substantially from one geographic area to another; […] 3) hydrological conditions, including for each aquifer in the management area, the total estimated recoverable storage as provided by the executive administrator, and the average annual recharge, inflows, and discharge; 4) other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water; […] 7) the impact on the interests and rights in private property, including ownership and the rights of landowners and their lessees and assigns in groundwater […]" (Porter 2014: 86).

Once the DFCs are delivered to the TWDB, the board generates Modeled Available Groundwater (MAG) reports for each DFC, "on the basis of groundwater models and the best available science" (Porter 2014: 86). A MAG is "the amount of water that the [TWDB] executive administrator determines may be produced on an average annual basis to achieve a desired future condition established under [the joint planning process of] Section 36.108". MAGs are then apportioned by the TWDB in each of the GMAs to the individual districts (Porter 2014). MAGs are used as the mandatory basis for groundwater availability in regional water planning and also a major consideration for permitting decisions in individual districts (Porter 2014) and GCD representatives are the only voting members for DFCs in the GMA meetings.

For example, Groundwater Management Area 1 comprises eighteen counties in West Texas, encompassing four GCDs,[40] all in the Ogallala Aquifer. These counties agreed unanimously in its Resolution No.1 in 2009 to support the goals, ideals and standards of the Groundwater Management Area 1, as well as support the Desired Future Conditions for groundwater reserves in the aquifer, viewed however as starting points to go forth for the next five years. They also agreed that constant monitoring from each GCD is necessary to measure the depths of the Ogallala Aquifer and to manage the resource in order to achieve the desired future conditions. The desired future conditions for the Ogallala Aquifer within Groundwater Management Area 1 and its 4 GCDs are:[41]

- 40 percent volume in storage remaining in 50 years in the North Plains GCD and also parts of Dallam, Hartley and Moore counties not part of a GCD.
- 50 percent volume storage remaining in 50 years in the High Plains Underground Water Conservation District, North Plains GCD, Panhandle GCD.

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[39] The two cases analyzed in more detail further down, the High Plains Underground Water Conservation District and the Edwards Aquifer Authority have pumping restrictions. See Section 4 and Section 5.

[40] These are: Hemphill County Underground Water Conservation District; portions of the High Plains Underground Water Conservation District; the North Plains Groundwater Conservation District; and the Panhandle Groundwater Conservation District.

[41] Attachment D: Resolution 2009-01 (Signed) Groundwater Management area #1, DFC Submission – Ogallala Aquifer, https://www.twdb.texas.gov/groundwater/docs/DFC/GMA1_DFC_Adopted_2009-0707.pdf (accessed 2nd March 2014).

- 80 percent storage remaining in 50 years in a 390-acre tract of land in Hemphill county provided that it remains part of the Hemphill Country Underground Water Conservation District (and not in the jurisdiction of the Panhandle Groundwater Conservation District, which in this case the Desired Future Condition for the tract would be 50 percent volume in storage remaining in 50 years).[42]

While establishing their DFCs, GCDs have the option to declare a part of an aquifer or an aquifer as 'non-relevant'. This means that GCDs do not have to establish a DFC for that particular portion of aquifer. The MAG is only calculated for aquifers or portions with DFCs and in the areas declared non-relevant, there is no DFC or modeled available groundwater-value estimated (Hermitte et al. 2015). Methods to calculate MAGs by the regional water plans are varied, from considering it equal to the average recharge, the volume that can be withdrawn without exceeding an acceptable amount of drawdown or spring flow decrease (typically based on a DFC), historical or projected water usage, or availability volumes from GCD management plans (ibid.). Once established, groundwater availability values are used by the regional water planning groups, as maximum amounts of groundwater that can be produced, in order to meet projected demands.

In areas where there is no GCD to manage groundwater, "there are no regulatory mechanisms to prevent actual groundwater withdrawals in excess of availability. Thus, if users can afford to increase their infrastructure and groundwater use, actual groundwater production may be equal to or exceed projections" (Hermitte et al. 2015: 18-19). These areas not covered by a GCD issuing DFCs present a management conundrum. These so-called 'white zones' or 'white areas' (Mace et al. 2008) can be prone to free-riding behavior by landowners, pumping as much water as they want regardless of the DFC. A possible result for these areas can be that neighboring GCDs vote for the annexation of such area under the jurisdiction of the GCD (as it has happened in Hays County) (TWDB 2015, pers. com.). The threat of such 'white zones' drove the Board of the Jeff Davis GCD to approve a 72 feet drawdown by 2070 as part of its DFCs even if it originally wanted only a 20 feet drawdown as it is near a county without a GCD (Jeff Davis GCD 2015, pers. com.). The possibility that a neighboring county would pump large volumes of groundwater led the Board of the GCD to approve a lax and 'generous' drawdown in order to guarantee and secure future groundwater abstraction levels within the DFC planning system. Following HB 1763 in 2005, GCDs can decide the DFCs of areas outside their districts, but that remain in their Management Area (Mace et al. 2008). These values will be used by the regional water planning groups and it is important that the GMAs incorporate any potential project even if it is in a 'white zone' as they can only be funded with state funds if they are included in the regional water plan (ibid.).

3.5.2 Appealing the DFCs

Stringent DFCs in certain counties have been fought by users claiming that water rights would be worthless if the DFC were to be finally approved. According to the rules, DFCs may be appealed: 1)"by a person with a 'legally defined interest' in groundwater within the

[42] This specific regulation affecting this 390-acre tract arises from a dispute between the owner of this piece of land and Hemphill County. Despite of the fact that the tract of land is within the county's boundaries the owner requested its inclusion on the Panhandle Groundwater Conservation District prior to the district's formation. The two districts sought the opinion of an attorney general about the matter in order to solve the issue. The rest of Hemphill County Groundwater Conservation District set its goal at 80 percent of available groundwater resources remaining in storage in 50 years' time, representing 400,000 acre feet of water which is more than 400 percent above the current demand (11,667 acre feet per year). The Canadian Record, 119(17), Thursday, April 23, 2009, http://texashistory.unt.edu/ark:/67531/metapth252747/m1/9/ (Accessed 2nd March 2014).

groundwater management area"; 2) by a district in or adjacent to the GMA; 3) or a regional water planning group for a region in the GMA (Porter 2014). Additionally, it is viewed by some local users that DFCs represent the latest episode in the State’s push towards centralization and therefore, according to a member of a GCD district, the establishment of DFCs is causing groundwater users not to create districts, because they fear possible future state intervention (Jeff Davis GCD 2015, pers. com.). In other instances, "so many districts have been formed to tell the state 'yes we got it', here is our fence, stay out of it" (Middle Pecos GCD 2015, pers. com.).

According to the original appeal process for DFCs, petitions need to be filed within one year of the approval of the DFC and if the substantive issues raised by the appeal have not been previously reviewed by the board (ibid.). The petition has to provide evidence that the GCD did not establish a reasonable DFC. Originally however, within the DFC appeal process, the legislature did not define 'reasonable' nor did it provide guidelines for the TWDB to use in determining whether a DFC is reasonable. The final determination is, in fact, responsibility of the GCDs (TWDB 2012a). This was later amended during the 82nd Legislature in 2011 when a more detailed process to approve DFCs by GCDs was approved. However, even though districts are required to prepare a detailed report on the DFC, the 82nd Legislature did not change the basic appeal process and the final determination whether a DFC is reasonable remains a GCD responsibility (ibid.).

The GCD, after board acknowledgement of the appeal, had 60 days to try to resolve the petition and it has to be submitted to the board of the TWDB no later than 120 days after the TWDB has acknowledged its reception. If the TWDB decides that the DFC is not reasonable, the GCD will have to revise the DFC in accordance with the recommendations issued by the TWDB. Ultimately however, the submission of DFCs once revised would still undergo a second administrative review to assess if it is physically possible. Users can contest to the TCEQ whether or not a GCD has rules to achieve the DFC and if the district is enforcing them (TWDB 2016, pers. com.). The executive administrator could then enforce action up to the dissolution of a district by the TCEQ. Therefore, the TCEQ is, by law, allowed to challenge the DFC definition process if a district refuses to join in the planning process or if the process "failed to result in adequate planning, including establishment of a reasonable DFC" (Dugat 2007: 7). As a result of this process, the TCEQ has the power to dissolve the board of a district following the Texas Water Code and dissolve the district or call an election for a new board.

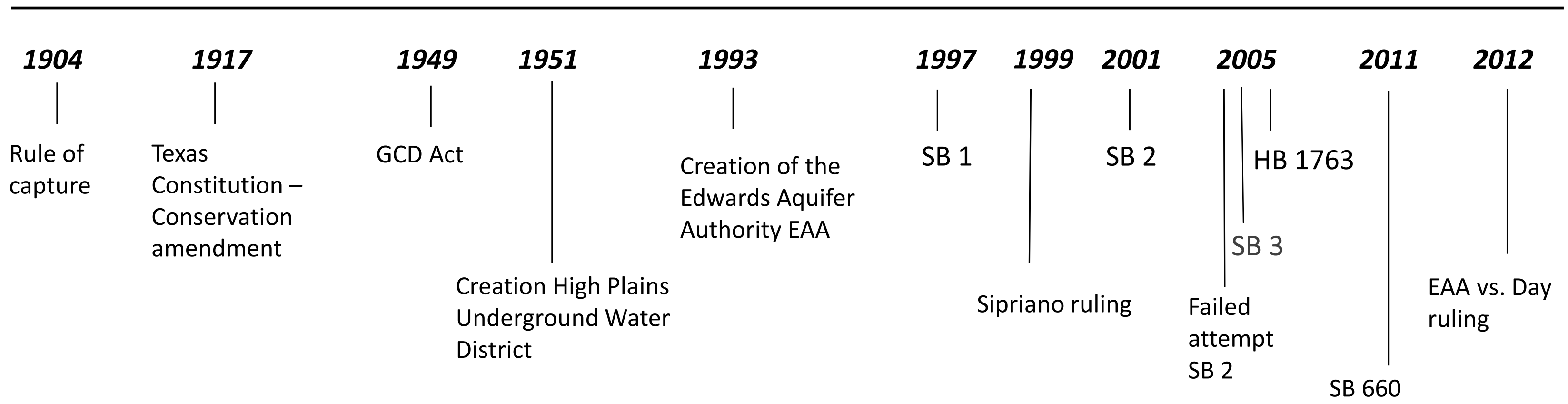
This was the case of a petition filed to the TWDB by Hemphill County in GMA 1 which, with an approved 80 percent of water remaining in the aquifer after 50 years, considered that some users had acquired water rights "in reliance on the 50/50 standard" and that it would violate constitutionally protected rights (TWDB 2010: 3). The current DFC as it stands could cause litigation from anyone interested in developing water there (TWDB 2010). Since other counties in the same GMA 1 have had their DFC set for the 50 percent storage remaining in 50 years, some users in Hemphill County requested an 'equal treatment' as the other counties (ibid.).

The existing type of review process of DFCs by the TWDB, according to the Sunset Advisory Commission, failed to ensure the fundamental fairness of the process as it "does not lead to a clear administrative conclusion as is common in other regulatory approaches. Without the ability to finally resolve petitions of the reasonableness of DFC's, the State cannot ensure the fundamental fairness of the process-especially for those harmed to seek redress" (Sunset Advisory Commission 2011c:30-31).

The revision process of DFCs however changed substantially during the 84th Legislature (in 2015), adding new provisions to Chapter 36 of the Texas Water Code and modifying the petition and appeal process through which users can challenge the reasonableness of DFC (Lloyd Gosselink 2015). These new rules shifted the decision from the TWDB to the GCDs and in later instance the local courts (TWDB 2015, pers. com.), authorizing that judicial appeals of a GCDs' final order on DFCs can be filed at a local district court with jurisdiction over any part of the GCD (ibid.).

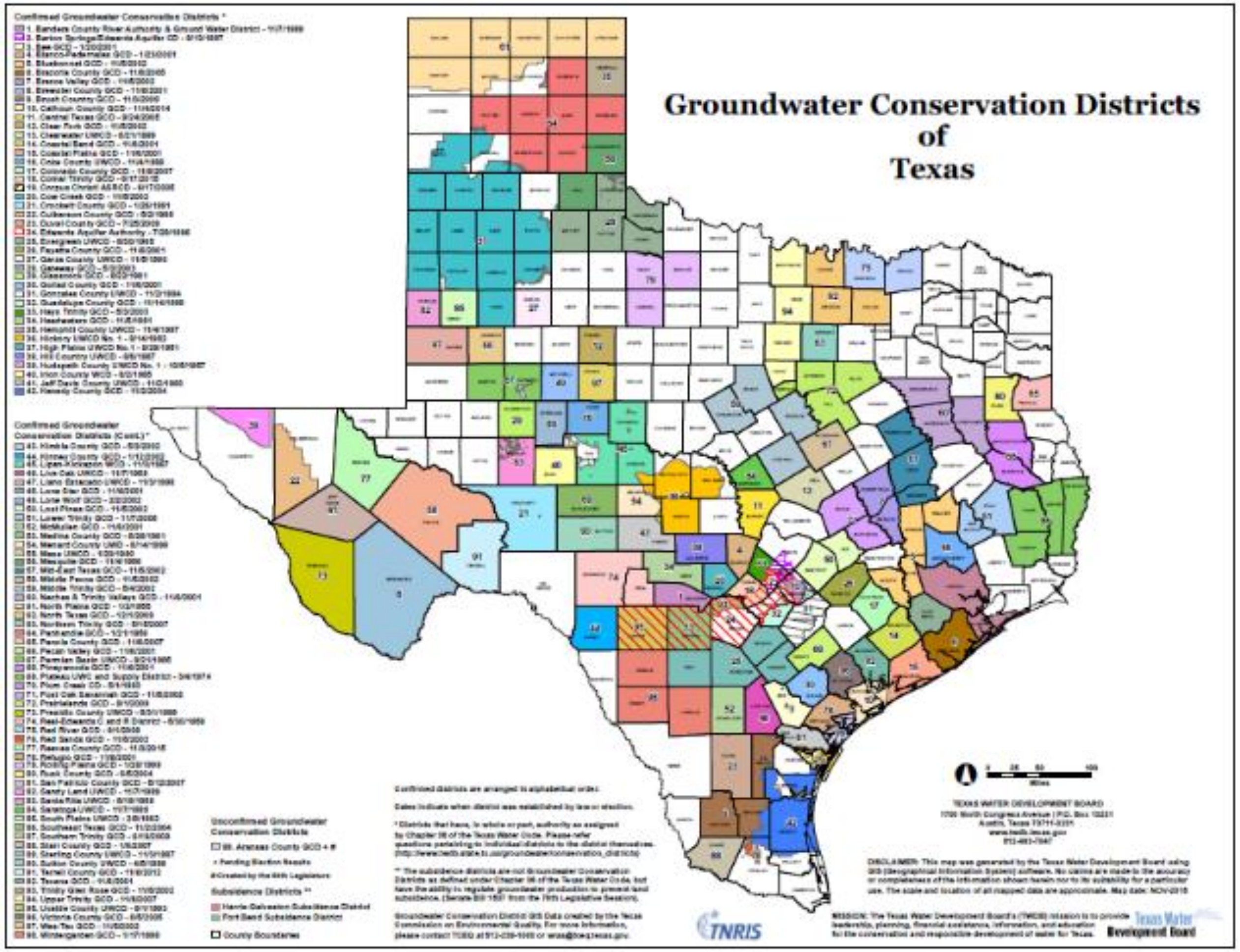
As defined by HB 200, individuals affected by DFCs can file petitions at the GCD and then the GCD sends the petition to the TWDB for an administrative review, issuing a technical report on the DFC. With the report, the GCD will contact the State Office of Administrative Hearings to appoint an administration law judge. The judge will hold a hearing and submit its findings and conclusions to the GCD. It is the GCD who ultimately will make a final ruling. If it rules in favor of the DFC, the petitioner can then take the case to the local district court. If the GCD rules against the DFC, then the GAM meets to revise the DFC for the GCD (TWDB 2016, pers.com.). This would seem to indicate that if a system of regulation can be questioned and appealed by individuals under the basis of seeking just compensations for the curtailment of rights, then all point and purpose for management and control disappears. Thus, these changes would seem to indicate that by giving appealing power of the DFCs to individuals via local courts, the control and management of groundwater by the state could potentially be weakened, remaining subjugated to individual prosecution and oversight.

Figure 7. Chronology of major legislation and events regarding groundwater management in Texas



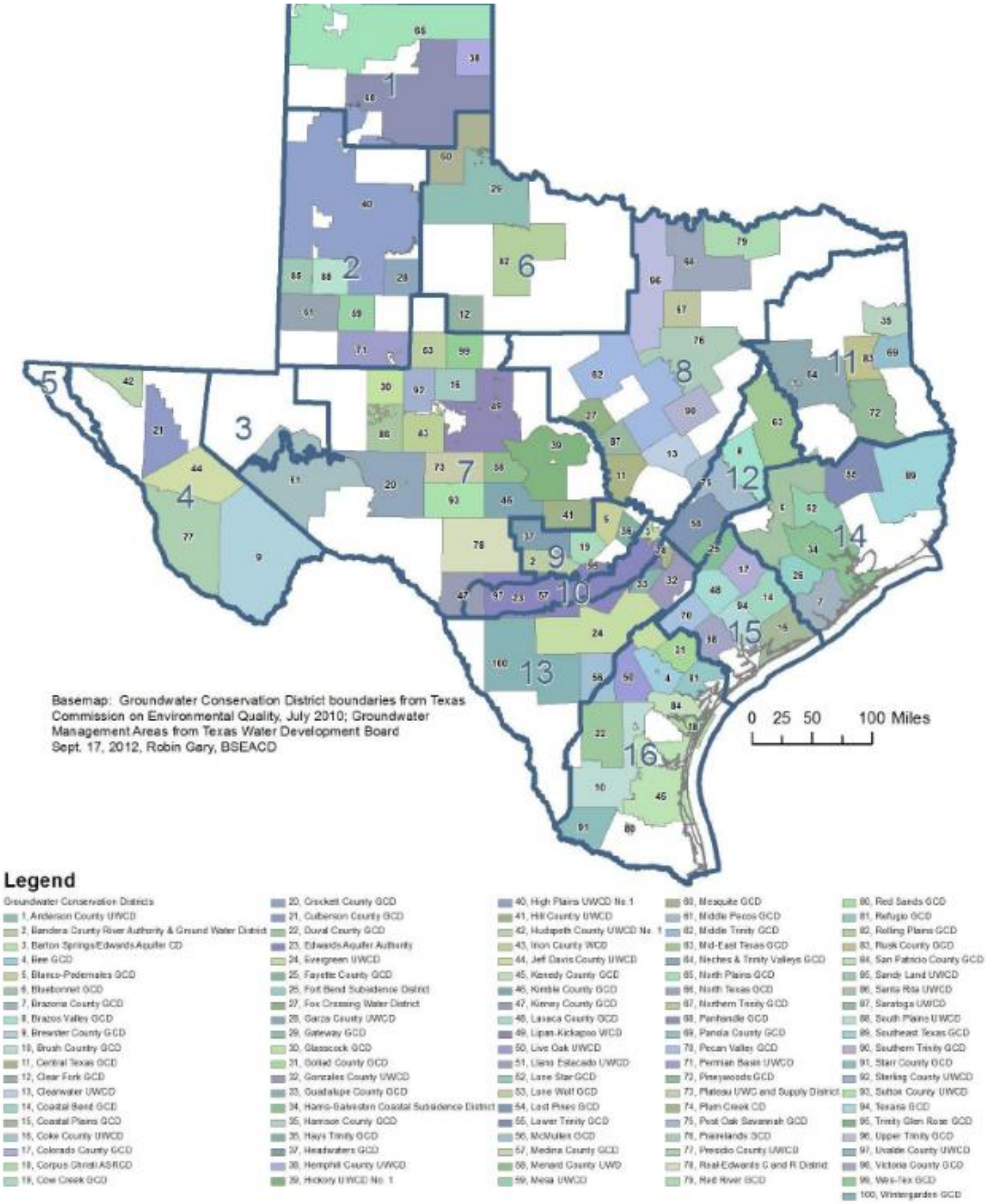
Note: SB 1: Senate Bill 1; SB 2: Senate Bill 2; SB 660: Senate Bill 660; HB 1763: House Bill 1763
Source: Authors.

Figure 8. Texas' groundwater conservation districts



Source: https://www.twdb.texas.gov/mapping/doc/maps/GCDs_8x11.pdf (Accessed 11th February 2016).

Figure 9. Groundwater Management Areas, Groundwater Conservation Districts and counties without GCDs



Source: Dupnik 2012.

4 Groundwater over-abstraction and regulation in the High Plains of Texas

4.1 The Ogallala Aquifer in Texas

The presence of groundwater in the Panhandle area of Texas is due to the existence of the High Plains Aquifer system (Figure 10). The High Plains Aquifer system is the largest in the US, 450,000 km2, underlying parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. It supplies water to 2.3 million people and to almost a quarter of the total water needs for agricultural production in the US (Gurdak et al. 2007; McMahon et al. 2007). The High Plains aquifer system is regionally divided into the northern High Plains aquifer, the Central High Plains aquifer, and the Southern High Plains aquifer. The High Plains aquifer system includes various geologic formations but the Ogallala formation is the main water-bearing unit, accounting for 77 percent of the High Plains Aquifer System extent (Qi and Christenson 2010) (Figure 10). The Ogallala aquifer was formed by ancient runoff from the Rocky Mountains (to the east), trapped in sandy soils, gravel, clay, and silt (George et al. 2011; Hornbeck and Keskin 2011a; Peterson and Bernardo 2003).

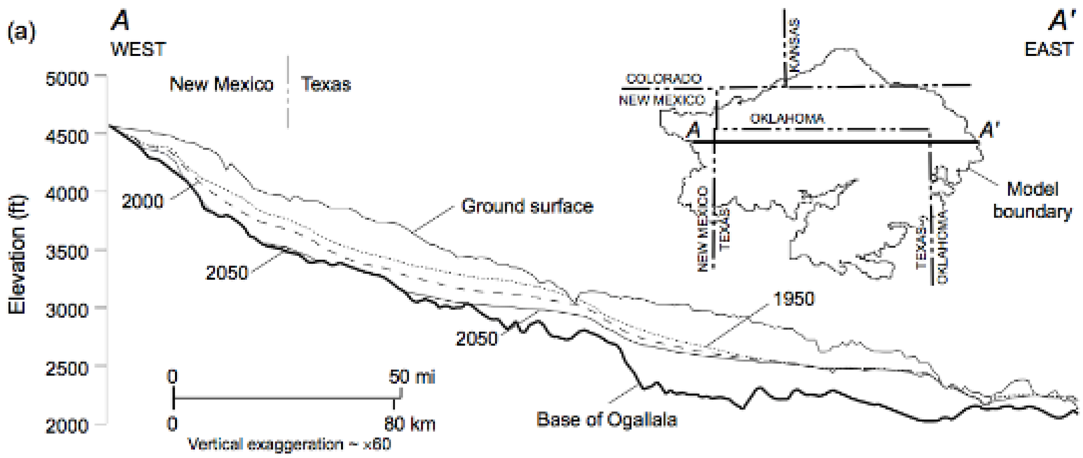
The Ogallala in Texas is essentially a non-renewable resource, receiving less than an inch of annual recharge due to minimal rainfall, high evaporation, and low infiltration (Scanlon et al. 2012; Hornbeck and Keskin 2011a). In Texas, the Ogallala Aquifer has a maximum thickness of 800 feet (244 meters) and freshwater saturated thickness averages 95 feet (29 meters) (George et al. 2011). Naturally occurring arsenic and fluorite concentrations in excess of the primary drinking water standards are also found (ibid.). Scanlon et al. (2010) have quantified that percolation and recharge beneath irrigated areas with groundwater only reaches the shallow subsurface and therefore does not replenish the deeper aquifer (with the exception of an area in the southeast).[43] Due to the fact that groundwater abstraction is the only source of water for irrigation and also considering this effect, it is possible to conclude according to these authors that nearly all groundwater is derived from storage (i.e. fossil water) and that water levels in Texas will continue to decline as long as irrigation continues (Scanlon et al. 2010).

Approximately 95 percent of groundwater pumped from this aquifer is used for irrigated agriculture (George et al. 2011). Throughout much of the aquifer abstraction exceeds recharge, which has resulted in a constant decline of groundwater levels over the last 60 years, in some cases of up to more than 300 feet (90 meters) in several areas (ibid.). The groundwater availability for this aquifer in 2010 was 6 million acre-feet per year and the reported water use in 2003 was of 6.3 million acre-feet per year (7.4 Bm3) (ibid.). However, groundwater abstraction is not uniform and areas with high rates of pumping can undergo much more critical deficits. Localized areas of groundwater overdraft had been reported as early as 1951 (Lehe 1986). Groundwater depletion from irrigation is most important in the Central and Southern High Plains areas. Reports from the United States Geological Survey with irrigation predevelopment data (pre-1950s) and post-irrigation development data (after 1970s to 2011) show a decline in average water-level change in for the Ogallala Aquifer in Texas of -39 feet (McGuire 2013). Estimates of the total volume of groundwater depleted in the Ogallala system

[43] The Ogallala would appear non-renewable because of how much groundwater is pumped every year (around 6 million acre-feet per year) (TWDB 2016, pers. com.). In this case the water table could fall faster than the movement of water downward through the vadose zone as recharge, indicating that most recharge has stopped for the aquifer (TWDB 2016, pers. com.). As Scanlon et al. (2010) point out, irrigation return flows could potentially be exceeded by the rate of water table decline, reducing the potential for recharge from irrigation return flows. “Therefore, nearly all irrigation water is derived from groundwater storage, and water levels should continue to decline as long as irrigation is practiced”, adding that groundwater cannot be managed sustainably “because recharge is too low” (Scanlon et al. 2010: 711).

between pre-development levels (i.e. before 1950) and 2007 differ, from 328 km3 (Stanton et al. 2011) to 385 km3 (Haacker et al. 2016), showing that different interpolation methods can alter resulting estimates by up to 15 percent. The section of the Ogallala formation that is impacted the most is in the southern portion of the High Plains, with the greatest percentage declines in average saturated thickness, declined by approximately 75 percent according to Haacker et al. (2016).

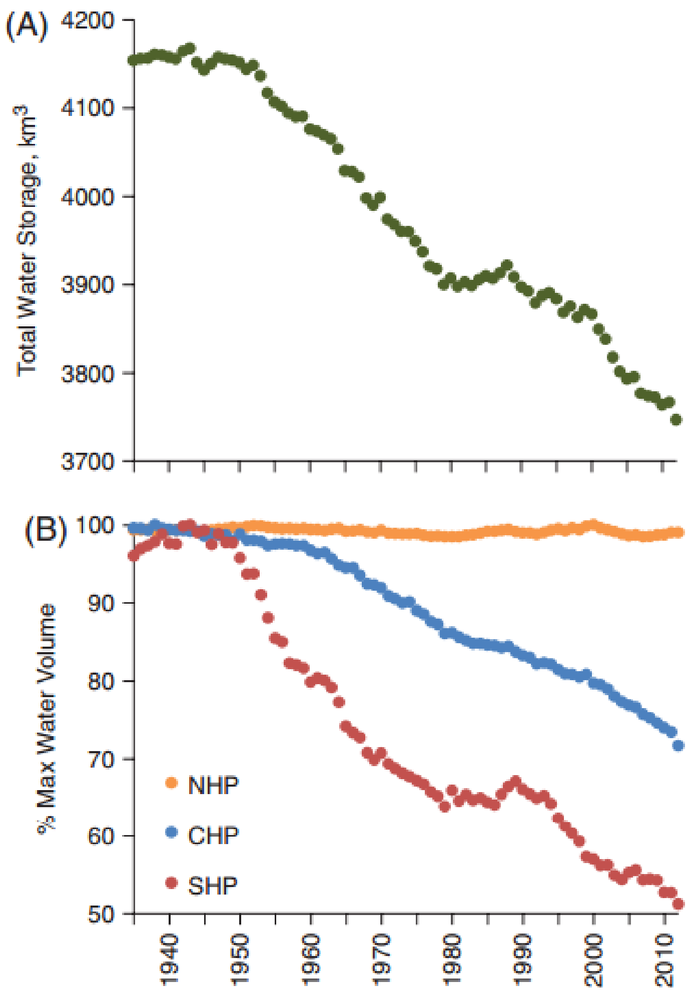
Figure 10. West-East cross section of the Ogallala Aquifer illustrating the relationship between the ground surface, aquifer base, and changing water table levels



Source: Dutton et al. 2001.

The High Plains aquifer system is also ranked first in the US in terms of groundwater withdrawals (Scanlon et al. 2012). In 2000, it was estimated that groundwater abstraction from the High Plains aquifer system represented 21.2 percent of the total groundwater abstraction in the US and of all groundwater abstracted in the High Plains, 97 percent of the groundwater pumped is for agriculture (Gurdak et al. 2007; Brown and Pervez 2014). In terms of irrigated surface, 30 percent of the total surface of the aquifer is irrigated (Scanlon et al. 2012), the rest being rangeland (56 percent of land uses) and 8 percent of non-irrigated agriculture (Qi and Christenson 2010). Economically speaking, the High Plains Aquifer is strategic as the market value of its agricultural products in 2007 was 35 billion USD (principally corn, soybeans, cotton, alfalfa, grain sorghum, and wheat, giving it the name 'granary of the US') (Brown and Pervez 2014; Scanlon et al. 2012).

Figure 11. (A) Total volume of water in the High Plains Aquifer (1935 to 2012); (B) Water remaining in storage from 1935 to 2012 as percentage of maximum water in storage



Source: Haacker et al. 2016.

The Ogallala Aquifer was first surveyed in the 1890s by the US Geological Survey but was considered of limited importance (mainly due to the poor techniques to abstract groundwater at the time, as windmill pumps could only provide small quantities of water, enough to irrigate 3 acres maximum) (Hornbeck and Keskin 2011a). Irrigation from wells in the High Plains in Texas started in the Panhandle region near Plainview, Hale County, in 1911. By 1914 there were about 140 wells completed in three districts (Broadhurst 1946). The early development of groundwater-fed irrigation until the 1930s was moderate, with only 160 new wells drilled (due to high costs and relatively low efficiency of low-speed pumps and oil-burning power (ibid.). This period coincided with a series of dry years from 1927 to 1934 causing an increase in well drilling (Barnes et al. 1949). In 1934 began the period of rapid increase in irrigation wells, accelerated in the 1940s (from 600 irrigation wells found in 1936 irrigated 80,000 acres to 5,500 wells in 1946 irrigating 650,000 acres and 10,500 in 1948 irrigating 1,250,000 acres) (Barnes et al. 1949; Broadhurst 1946).

In terms of irrigation technology, gravity irrigation was used in the 1950s, progressively giving way to sprinkler irrigation in the 1970s and 1980s and more rapidly after 1989 (reaching 72 percent of the relative proportion of irrigation technology used in Texas by 2000) (Colaizzi et al.

2009). Drip irrigation also started being used around the mid-1980s, mainly for cotton production (ibid.). The estimated surface with drip irrigation went from around 8,800 hectares in 2000 to some 100,000 hectares in 2004 (ibid.).

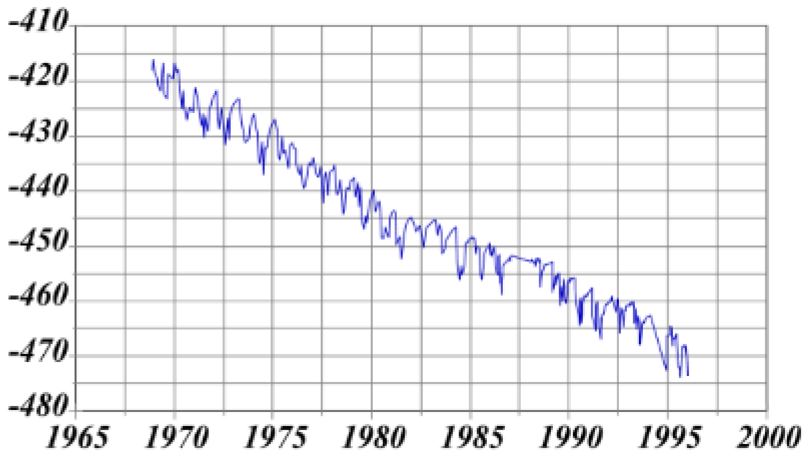
During the first half of the twentieth century, the dominant crops found in the High Plains in Texas were mainly wheat, alfalfa, and sorghum grain shifting to more corn and soybeans after the 1950s (Brown and Pervez 2014). In the 1980s the region represented 20 percent of the USA grain production for cattle feed, and accounted for around 24 percent of the total value of exported commodities (Lehe 1986).

Profits linked to agricultural output were expected to drive groundwater demand for irrigation after the 1970s. This would be due to increasing commodity prices and the adoption of cost-reducing and output-increasing technology which lengthened the period over which irrigation is profitable (Mapp 1988). This trend was reflected by a peak in cultivated area in Texas in 1974 (2.42 million hectares) but was limited by increasing energy prices (which increased pumping costs) as well as well yield reduction. A relative stabilization of commodity prices led to overall reduction rates after 1974 and throughout the 1980s (Musick et al. 1990 in Colaizzi et al. 2009). By 2004 however, the irrigated area in the Texas High Plains was nearly the same as 1958 (1.87 million hectares). The maintenance of levels was also probably driven by a severe drought in the early 2000s. The decline in well yields required more wells to maintain previous pumped volumes (Colaizzi et al. 2009).

The demand for corn as livestock feeder and more recently for ethanol production has been keeping the increase in production of this crop in the region after 2000 (Brown and Pervez 2014). The increase in commodity prices since 2000 has also been driving the increase in production, affecting land use and cropping patterns (average national corn prices rose 81 percent between 2002 and 2007, 82 percent for soybeans, and 90 percent for wheat) (ibid.). Corn remains the most harvested crop in the High Plains, making up 47 percent of the total irrigated area (ibid.). Lately, the expansion in irrigated area has been driven by the USA Farm Bill which encourages biofuel production. This represents large incentives for farmers to grow corn all year long as a monoculture, contributing also to higher corn prices due to the increase in demand (Basso et al. 2013). The use of corn for ethanol has therefore been driving, according to Brown and Pervez (2014). Additionally, the production of this crop received an additional incentive since the 2005 Energy Policy Act, the US has been increasing the amount of renewable fuels in its energy production and fuel supply. Currently, there are 47 ethanol production plants in and adjacent to the High Plains aquifer (ibid.).

In the High Plains, estimates by Scanlon et al. (2012) have established that the amount of groundwater depleted from the High Plains aquifer between the 1950s and 2007 is around 330 Bm3. Early signs of depletion were already measured in the 1940s, with average declines in the Panhandle area of Texas of up to 7.5 feet between 1938 and 1946 (Broadhurst 1946). According to calculations by Scanlon et al. (2012), the volume of groundwater depleted between the 1950s and 2007 would represent around 8 percent of the groundwater present in the aquifer before irrigation (approximately 4,000 Bm3) (ibid.). Aquifer depletion is spatially uneven across the High Plains, with mean water table declines of 0.3 meters in Nebraska, 11 meters in Texas, and 7 meters in Kansas (ibid.). Serious spatial depletion (more than 35 meters between the 1950s and 2007) is localized in about 4 percent of the High Plains land area (mainly in the center, - Kansas and Oklahoma, and north parts of the southern plains, - West Texas) (Figure 14) (ibid.). Despite such level of groundwater abstraction, agriculture in the High Plains has been expanding. The study by Brown and Pervez (2014) shows evidence of an overall net expansion in irrigated land of over 519,000 hectares (8.7 percent) between 2002 and 2007,[44] which represents over 97 percent of the total net national irrigated area increase in the US. Groundwater modeling (Figure 13) indicates a continuous increase in groundwater abstraction levels by 2050 and declines in water levels and saturated thickness in most areas of the Ogallala Aquifer as pumping rates continue (Dutton et al. 2001). Results from the model indicate that drawdown from 1998 to 2050 is predicted to be more than 150 feet (45 meters) in some areas given the forecast amount of pumping (ibid.). However, results also show a total remaining volume of groundwater in 2050 of 74 percent of the 1998 volume levels (ibid.).

Figure 12. Depth to water in Well 06-36-602, Carson County (Ogallala aquifer) (in feet)



Source: http://www.twdb.state.tx.us/publications/reports/HydrologicAtlases/doc/HA-07.pdf (Accessed 28th of January 2015).

4.2 Tax exemption in the Ogallala Aquifer

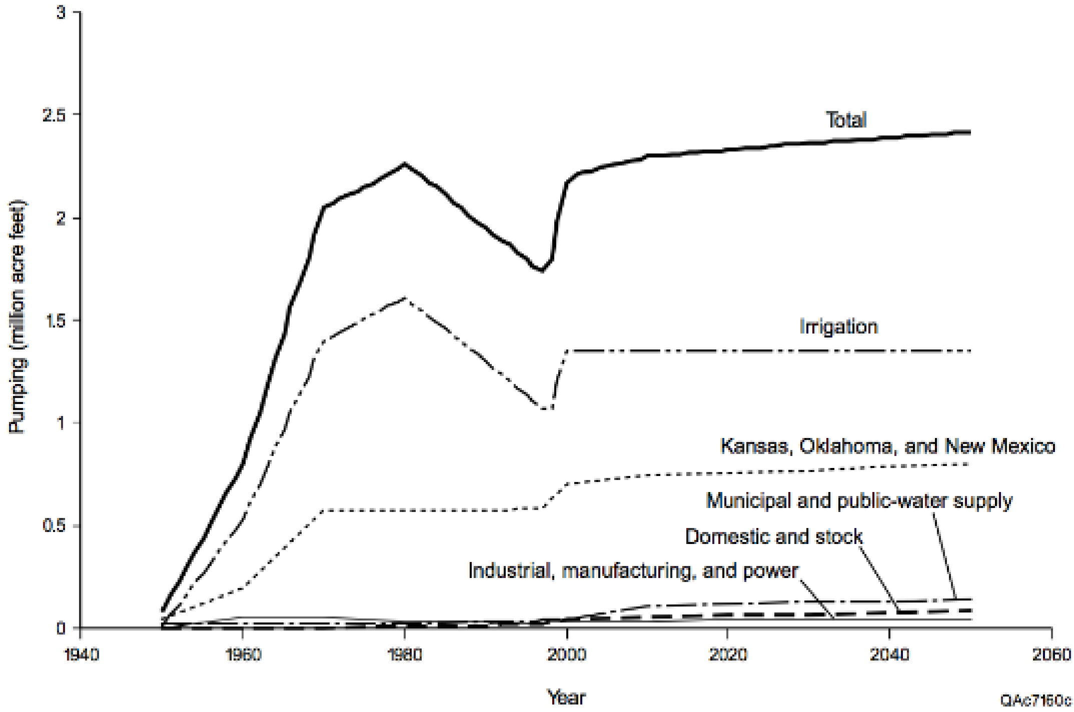
Due to the decrease in groundwater levels, in 1965 the Ogallala's groundwater was declared a non-renewable resource and treated similarly to timber and minerals. This legal decision induced a new interpretation of the federal tax code, allowing irrigating farmers depreciation allowances for declines in groundwater levels. It also amplified the effects of private abstraction, and resulted in a de facto incentive to continue pumping without suffering the consequences of groundwater depletion (Hornbeck and Keskin 2011b). The US Court of Appeals found that farmers in the Ogallala were entitled to these allowances for declining groundwater levels under their properties (ibid.). A depreciation allowance, based on estimated declines in the water table, is therefore given to farmers abstracting water (Hornbeck and Keskin 2011b).

This applies to properties bought since 1948, with the tax benefit based on two factors: 1) the saturated thickness of the aquifer underlying the property at the time of acquisition; 2) the cost of land attributable to water. The GCD will produce maps showing the extent and location of groundwater depletion (reduction in saturated thickness) and the landowner will be able to evaluate the depletion of the water supply. Based on cost-in-water tables approved by the Internal Revenue Service, the landowner can calculate the depletion allowance which will reduce the income tax to be paid (Rayner 1970). The Internal Revenue System claim is considered when it can be demonstrated that groundwater "is being depleted and the rate of recharge is so low that, once extracted, the water is lost to the taxpayer and immediately

[44] Compared to Nebraska with a net increase in irrigated area between 2002 and 2007 of 16.3 percent, Texas showed a smaller increase in irrigated area of 5.5 percent (Brown and Pervez 2014).

succeeding generations".[45] Landowners who have not previously claimed such deduction would "need to establish the number of feet of saturated material they had beneath their land at the time of acquisition, the cost of the water which has been determined by comparing actual land sales with and without ground water at the date of land acquisition and the decline in the water level during the tax year. The water district contracts with a professional land appraiser, who documents land sales occurring within portions of the district each year. The average selling price for dryland farm sales is subtracted from the average selling price for irrigated farms. The price difference is the value of the water".[46]

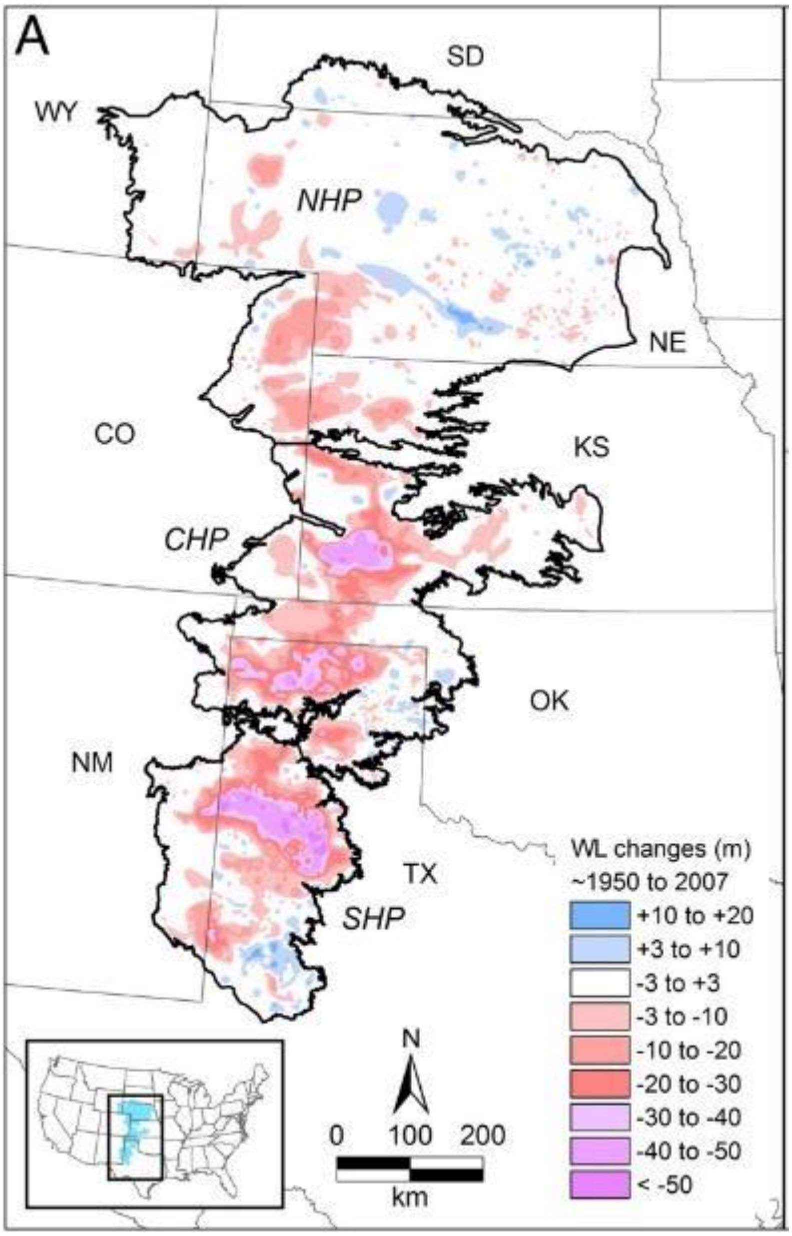
Figure 13. Historical and modeled change in total annual rate of groundwater abstraction for irrigation, drinking water supply, and other uses in the Ogallala aquifer



Source: Dutton et al. 2001.

[45] IRS Publication 225 (2004) Farmer's Tax Guide, Page 46, Department of the Treasury, Internal Revenue Service, https://www.irs.gov/pub/irs-pdf/p225.pdf (Accessed 10th December 2015).
[46] High Plains/Midwest AG Journal 2000 "IRS okays cost-in-water income tax depletion allowance", Saturday, 1st January 2015, http://www.hpj.com/archives/irs-okays-cost-in-water-income-tax-depletion-allowance/article_c297d110-4a75-11e4-b08b-10604b9f1ff4.html (Accessed 10th December 2015).

Figure 14. Measured changes in groundwater levels from pre-development years (1950s) to 2007 in the High Plains Aquifer System



Source: Scanlon et al. 2012.

4.3 Rules of procedure of a GCD: the High Plains Underground Water Conservation District[47,48]

The High Plains Underground Water Conservation District (HPUWCD) was created in 1951 by 13 Southern high plains counties in accordance with the Underground Water Conservations Districts Act passed by Texas legislature in 1949. This GCD depended on a levy of five cents per acre and raised a total of USD 42,000 for 1952, its first year of existence (Teel 2011). The GCD covers an area of 3.07 million hectares of which approximately 1.01 million hectares are

[47] The High Plains Underground Water Conservation District was the first local district to be created in Texas in 1951 after the Texas Legislature provided for the voluntary creation of groundwater conservation districts in 1949.

[48] The source for this section are the High Plains Underground Water Conservation District Rules, amended on November the 12th, 2013, www.hpwd.com/rules-and-management-plan/district-rules/ (Accessed 6th of August 2014).

irrigated with groundwater.[49] There are around 13,000 center pivots for agriculture. The estimated groundwater withdrawal from the Ogallala Aquifer by users in the HPUWCD is 4.5 Bm3 (in 2010) (Oliver 2011). The annual budget for the HPUWCD was 2,015,000 USD in 2012, with 23 full time employees (Dupnik 2012).

The last regulation for the GCD stated the different rules for wells. The drilling and alteration of wells is controlled by permits (Rule 3.1) (This includes the replacement of wells and the alteration of size of the well or pump – Rule 4.3, 4.4., 4.5). Permits are not needed for a well that does not have the capacity to abstract more than 25,000 gallons (94.6 m3) of water per day or that is used solely for domestic use regardless of its size (Rule 7.1). Groundwater is to be used only for beneficial purposes and permits establish the maximum limit of groundwater abstraction (Rule 3.2 and Rule 5.3).[50] According to these rules, wells are also required to be equipped with meters (Rule 5.11) and all well owners will have to issue groundwater production reports annually and submit them to the District (Rule 5.17) as well as to keep well logs when drilling, equipping or completion of wells, and of the production or use of groundwater (Rule 6.3).

Staff from the Conservation District are allowed to enter any public or private property in order to inspect and investigate conditions relating to the quality of water or the compliance with any rule, permit or other order of the District (Rule 3.6). The District Board has the power to seal wells if no application has been made to obtain a permit; misrepresentations have been made by the owner regarding the well characteristics; the owner has violated any provision of the state law or District rules; the well is abstracting at a higher rate than allowed by its permit; the well is not drilled within ten yards of the proposed well site specified in the permit; and the Board has revoked or cancelled a permit (Rule 3.8). The District can issue rules through notification of rulemaking hearings 20 days before the hearing, and comments to the rules can be submitted orally at the hearing or in writing (Rule 9.1 and 9.3).

The enforcement of rules policy for the district differentiates between minor and major violations (Appendix A, Enforcement policy and penalty schedule). The General Manager of the GCD will recommend to the board the appropriate settlement for the violation. This can be: (1) tender an offer to settle the violation; (2) institute a civil suit in an appropriate court; (3) or both. Minor violations of the district rules are acts such as: failure to conduct a meter reading within the required period; failure to submit the annual production reports on time but still submitted within the first 60 calendar days after the deadline; not providing the driller's log before starting production for new wells; and failure to install and approved meter by the applicable deadline. The first minor violation will represent a civil penalty of 100 USD, the second 250 USD and the third violation by a member of the district will be considered a major violation.

Major violations subject to fines (300 USD for the first one, 500 USD for the second and a civil suit for the third) include acts such as: failure to obtain a permit from the District; failure to comply with permit terms; failure to close or cap an open well; failure to submit timely production reports after the first 60 calendar days from deadline; committing waste or pollution; tampering with a meter or seal or bypassing a meter. The enforcement of rules by the

[49] HPWD Management Plan 2014-2024, http://static1.squarespace.com/static/53286fe5e4b0bbf6a4535d75/t/544fde09e4b07b58025e6e3a/1414520329694/ManagementPlan.pdf (Accessed 13th July 2015).
[50] See further below in this section for a detailed characterisation of the abstraction limits.

District is supervised by a court and any violation of the rules of the District is subject to civil penalty or injunctive relief (court ruling). Civil penalties for the violation of rules will be set at 10,000 USD per violation or a lesser amount based on the severity of the violation set forth in a civil penalty schedule by the District board.[51] The district has also issued well spacing requirements (Rule 4.1, Table 2) to minimize the drawdown of the water table and control subsidence, prevent interference between wells, degradation, or waste.

Table 2. Well spacing requirements for wells drilled in the Ogallala Aquifer

Well Production (Factor that determines spacing of proposed wells)	***Minimum Distance from nearest well or proposed well site***	***Minimum Distance from Property Line***
17.5 to 70 g.p.m.	100 yards	25 yards
> 70 to 165 g.p.m.	200 yards	50 yards
> 165 to 265 g.p.m.	300 yards	75 yards
> 265 to 390 g.p.m.	350 yards	87.5 yards
> 390 to 560 g.p.m.	400 yards	100 yards
> 560 to 1,000 g.p.m.	500 yards	125 yards
> 1,000 g.p.m.	540 yards	135 yards

Note: g.p.m. = gallons per minute; 1 gallon = 4.54 liters; 1 yard = 0.9144 meters.
Source: High Plains Underground Water Conservation District, http://www.hpwd.com/ag-and-urban-water-use/water-well-permitting (Accessed 22nd December 2013).

4.4 Desired Future Conditions and control of groundwater abstractions in the HPUWCD

In the Ogallala Aquifer, the desired future conditions approved as part of the Regional Groundwater Management Plan (in GMA 1 and GMA 2) establish that a varying percentage of all saturated thickness will remain in the aquifer after 50 years (in GMA 1 and GMA 2 portions overlying the Ogallala aquifer and the HPUWCD). For the southern portion of the Groundwater Management Area 2, specific level declines have been established (in feet) for the next 50 years by county.[52] According to the rules of procedure for the HPUWCD, the conservation goal for the district is to maintain 50 percent of the saturated thickness of the Ogallala Aquifer underground by 2060 (Rule 1 and Rule 5). The overall reduction for the Ogallala Aquifer in GMA 1 and GMA 2 is divided by county (with different allocations per district as will be reviewed later in Section 7.3.1), regional planning area, and river basin for each decade between 2010 and 2060.

As per the implementation of the District's management goal of 50 percent saturation of the Ogallala Aquifer by 2060 and in fulfillment of the Texas Water Code, the GCD regulates that for all existing, pre-existing, and new wells a gradual adjustment will be imposed in order to meet

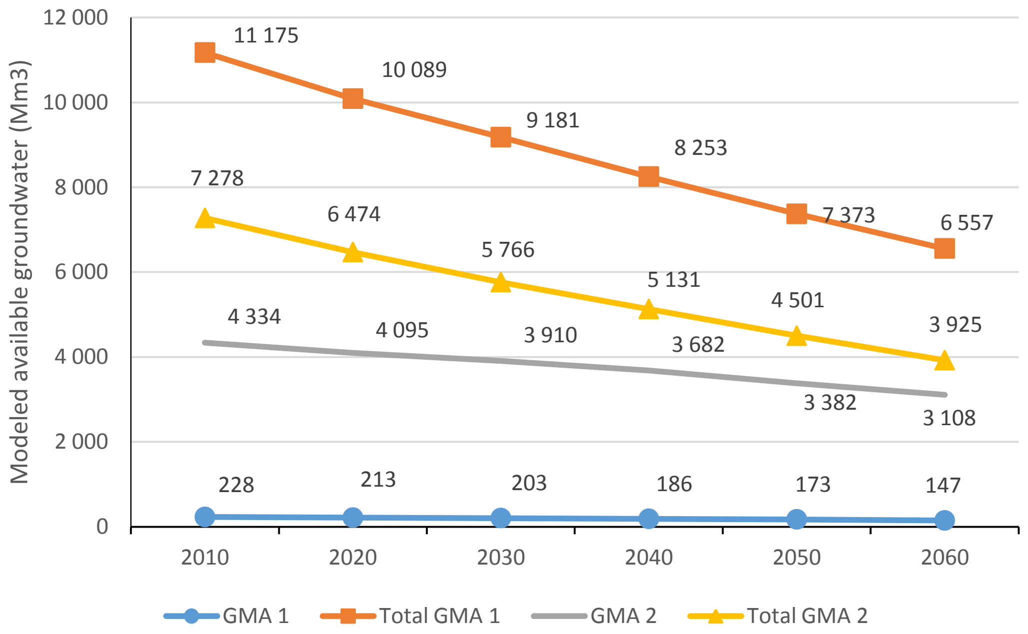
[51] If the district prevails in a lawsuit to enforce any of its rules, the district can also seek the recovery of any fees incurred before the court. There is an exception to this rule however. The district will not impose penalties to its users in the case where groundwater abstraction exceeds the granted permit if such abstraction is done to comply by an order issued by the Texas Commission of Environmental Quality and related to remediating groundwater or soil contamination, supplying public water through an emergency connection, or a similar TCEQ order specific to that user that necessitates groundwater production above the Allowable Production Rate (Rule 3.10).

[52] The water table declines vary according to each county in this part of the aquifer. The difference goes from one foot over 50 years for counties such as Howard to a maximum decrease of 74 feet in Dawson county and 70 feet in Gaines country (http://www.twdb.texas.gov/groundwater/management_areas/dfc_mag/GMA_2_DFC.pdf, Accessed 26th January 2015).

with the DFC. The cap was therefore defined as the allowable production rate for any well within the district, established at 5,334 m3 per hectare[53] per year between January 2012 and December 2013. Then follows a further reduction down to 4,572 m3 per hectare[54] per year between January 2014 and December 2015 and down to 3,810 m3 per hectare[55] per year from January 2016 onwards (Rule 5.3). Reductions of the cap following the model were established as progressive in order to fulfil the GCD's DFC by 2060.

The DFCs established for the HPUWCD were defined as to comply with the 'modeled available groundwater' as defined by the TWDB. This is, according to the Texas Water Code (Chapter 36) "the estimated average amount of groundwater that may be produced annually to achieve a Desired Future Condition" (Jigmond 2012: 6). Given that the Ogallala Aquifer overlies two different GMAs (GMA 1 and GMA 2), different DFCs have been set within the HPUWCD (Figure 15). For GMA 1 (the Ogallala portion of the HPUWCD), modeled declines were defined starting from an initial amount of groundwater in the aquifer in 2010 of 228 Mm3 down to 147 Mm3 in 2060. For GMA 2, the modeled decline between 2010 and 2060 was from 4.3 Bm3 down to 3.1 Bm3. The modeled depletion is established in order to "minimize the occurrence of dry cells" within the model. These become 'inactive' in the model when, as Jigmond (2012: 16) wrote, "the water level in the cell drops below the base of the aquifer. In this situation pumping cannot occur for the remainder of the model simulation."

Figure 15. Modeled available groundwater for the HPUWCD in the Ogallala Aquifer (in GMA 1 and GMA 2) as a result of DFCs between 2010 and 2060



Note: data only shows abstraction levels for the Ogallala Aquifer (the HPUWCD also pumps water from two other formations, the Edwards-Trinity Aquifer, and the Dockum formation).
Source: with data from Jigmond 2012 and Oliver 2011.

Groundwater users abstracting in excess of the Allowable Production rate will pay 25 USD per acre foot produced in excess for the first time, 75 USD per acre foot the second time and 225

[53] In the original it was established at 1.75 acre-feet per acre of land.
[54] In the original it was established at 1.5 acre-feet per acre of land.
[55] In the original it was established at 1.25 acre-feet per acre of land.

USD per acre foot produced in excess for the third occurrence of the violation. A fourth and subsequent violations for production will result in a civil suit (Appendix A). According to District rule, failure to pay the fine within 90 days of notification will represent an additional 25 USD per acre foot produced in excess. Additional failure to pay the fine within 180 days of notification will result in a civil suit.

As per the District management's goals, a water banking system was expected to be in place by January 2013 in order to allow producers to bank groundwater during normal and above-normal precipitation years in order to be used during recurring drought periods. The district will set up an online water banking system that will place in reserve for use at any point during the next three years. At the end of 2014, approximately 67 producers had participated in the system. District rules concerning this issue were revised in August 2014. For 2015, the banking system will be replaced by a 'Conservation Reserve' starting at 0.50 acre-feet per acre of land for eligible users. According to the District rules, "The reserve shall not be assigned or transferred to other acreage without District approval and withdrawals from the reserve shall not exceed 0.50 acre-feet per acre per year." The District updated its reporting procedures in 2015 and established an online system to report water use. For those wishing to participate in the conservation reserve program, the GCD offers a 'detailed approach' by which users have to calculate and submit detailed usage records (entering the specific amount of water that was used) so that the reserve is properly calculated and documented.[56]

Despite these conservation efforts, well monitoring for the High Plains Underground water Conservation district indicates a decline between 2002-2012 (between 0.9 and 21.4 meters) (The Cross Section 2012), representing a decrease of around 18 percent of the total economically accessible volume of groundwater in storage in the Ogallala Aquifer between 2003 and 2012 (Figure 17). Modeled groundwater drawdown for 4 counties on the Ogallala Aquifer (in the North Plains GCD, north of the HPUWCD) indicated in 2013, that if current rate continues, about 9 percent of the area would suffer groundwater depletion greater than 30 meters and 2 percent of the area greater than 50 meters by 2060 (Hernandez et al. 2013). This would indicate that groundwater conservation efforts are insufficient because groundwater recharge and use are not well assessed. Conservation measures are also in place and would be sufficient but they are not fully enforced and users keep applying for well permits in the district. In 2013, there were 1,219 new well applications received for well registration at the GCD (of which 1,207 were from within the Ogallala Aquifer boundaries) and another 1,133 permit applications in 2012.[57] In its 2015 report, the HPUWCD issued 493 new well permits (of which 154 permits were for wells with a production capacity of 10 liters per second).[58] These are not exempt wells (as they are producing more than 17.5 gallons per minute). In its annual water level measurement report for 2015, the HPUWCD reported an average change of aquifer levels in feet of -10.27 between 2005 and 2015 (with an average change between 2014 and 2015 of -0.56) (HPUWCD 2015a).

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[56] According to the HPUWCD website, http://www.hpwd.org/reporting/ (Accessed 27th January 2016).

[57] High Plains Underground Water Conservation District No.1, 2013 Annual Report, file:///C:/Users/ict/Downloads/2013%20HPWD%20Annual%20Report.pdf (Accessed 10th August 2014).

[58] According to the 2015 Annual report, the HPUWCD issued 76 permits for wells with a production capacity of 70 gallons per minute (4.4 litres per second), 154 for wells with a production capacity of 165 gallons per minute (10.4 litres per second), 106 permits for wells with a production capacity of 265 gallons per minute (16.7 litres per second), 48 permits for wells with a production capacity of 390 gallons per minute (24.6 litres per second), 73 permits for wells with a production capacity of 560 gallons per minute (35.3 litres per second), and 7 permits for wells with a production capacity of 1,000 gallons per minute (63 litres per second) (HPUWCD 2015b).

The GCD also monitors agricultural practices to prevent groundwater waste resulting from the release or loss of irrigation water.[59] In 2013 there were 7 complaints raised by the GCD and within 7 days owners or the operators had been notified formally via 'first notice letters'. All cases were resolved after the initial visit by the GCD officials. In 2012 there had been 48 complaints with written reports to owners but no 'second notice' nor attorney letters were mailed, and no lawsuits were filed. All 48 complaints were resolved after field check by the GCD personnel.[60] The GCD also started in 2012, and is supposed to continue every 5 years, an inventory of center pivots in operation and report it in the annual report (the center pivot inventory for 2013 was not conducted though).

Figure 16. Average changes in depth to water in feet from observation well measurements in the High Plains Underground Water Conservation District

Average Changes in Depth To Water In Feet During 2012 From Observation Well Measurements in 2013

(+) Water Table Rise *(-) Water Table Decline*

	Number of Observation Wells Maintained	Average Annual Change 2003 to 2013 *(10-Year)*	Average Annual Change 2008 to 2013 *(5-Year)*	Average Annual Change 2012 to 2013 *(1-Year)*
Armstrong	10	+ 0.44	+ 0.16	- 0.11
Bailey	115	- 0.79	- 1.38	- 1.95
Castro	100	- 1.90	- 2.63	- 2.72
Cochran	75	- 0.70	- 1.02	- 0.87
Crosby	75	-0.75	- 1.43	- 1.61
Deaf Smith	88	- 0.79	- 1.26	- 1.17
Floyd	103	- 0.82	- 1.48	- 2.10
Hale	119	- 1.51	- 2.19	- 2.98
Hockley	97	- 0.60	- 0.94	- 1.15
Lamb	130	- 1.56	- 2.09	- 2.90
Lubbock	132	- 0.43	- 0.81	- 1.26
Lynn	78	+ 0.01	- 0.54	- 1.37
Parmer	107	- 1.99	- 2.60	- 3.13
Potter	7	+ 0.03	- 0.27	- 0.28
Randall	50	- 0.13	- 0.22	- 0.15
Swisher	69	- 0.45	- 0.15	- 1.05
DISTRICT	**1,355**	**- 0.89**	**- 1.40**	**- 1.87**

Source: The Cross Section 2013.

[59] This is defined by the district rules as any action "wilfully or negligently causing, suffering, or permitting groundwater escape into any river, creek, natural watercourse, depression, lake, reservoir, drain, sewer, street, highway, road, or road ditch or onto any land other than that of the owner of the well; or groundwater pumped for irrigation that escapes as irrigation tail water onto land other than that of the owner of the well unless permission has been granted by the occupant of the land receiving the discharge". High Plains Underground Water Conservation District No.1, 2013 Annual Report, file:///C:/Users/ict/Downloads/2013%20HPWD%20Annual%20Report.pdf (Accessed 10th August 2014).

[60] High Plains Underground Water Conservation District No.1, 2012 Annual Report, file:///C:/Users/ict/Downloads/2012%20Annual%20Report.pdf (Accessed 10th August 2014).

Figure 17. Changes in total volume of groundwater stored in the Ogallala Aquifer between 2003 and 2012

Changes in total volume and economically accessible volume of water in storage in Ogallala Aquifer (2003-2012)

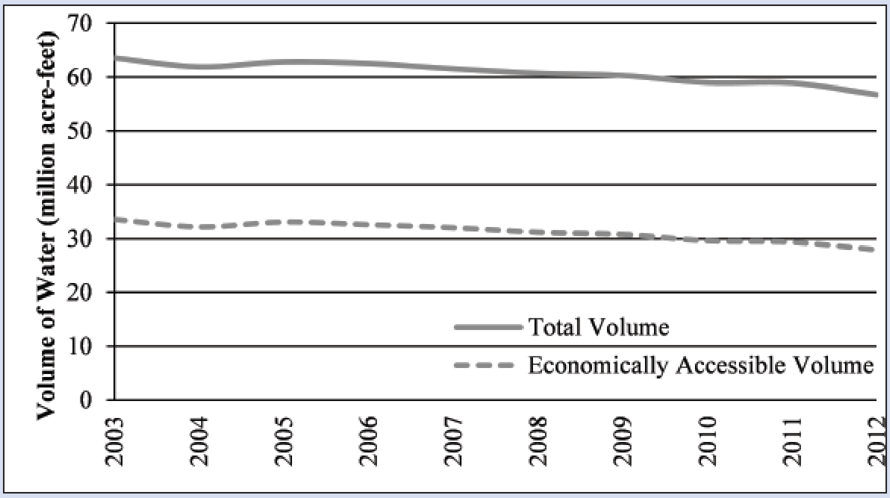


FIGURE 4 – Changes in total volume and economically accessible volume of water in storage in the Ogallala Aquifer.

Volume and percent changes in total volume of water in storage in the Ogallala Aquifer within the HPWD (2003-2012)

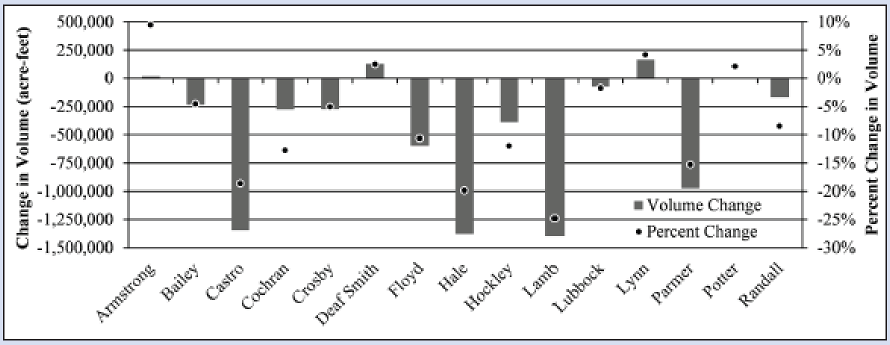
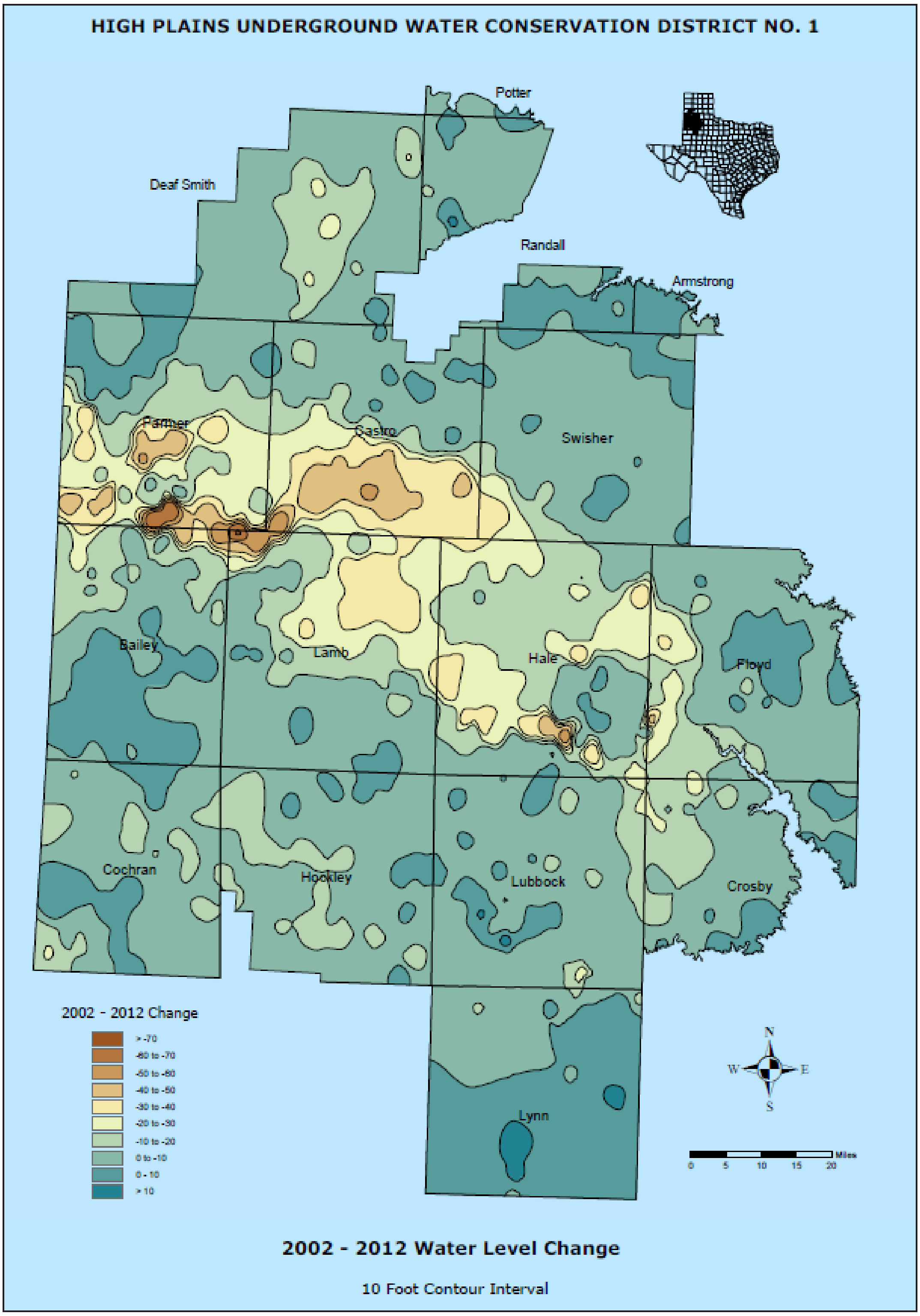


FIGURE 5 – Volume and percent changes in total volume of water in storage in the Ogallala Aquifer in the HPWD from 2003 through 2012.

Source: The Cross Section 2012.

Figure 18. Groundwater level changes in the High Plains Underground Water Conservation District between 2002 and 2012 (in feet)

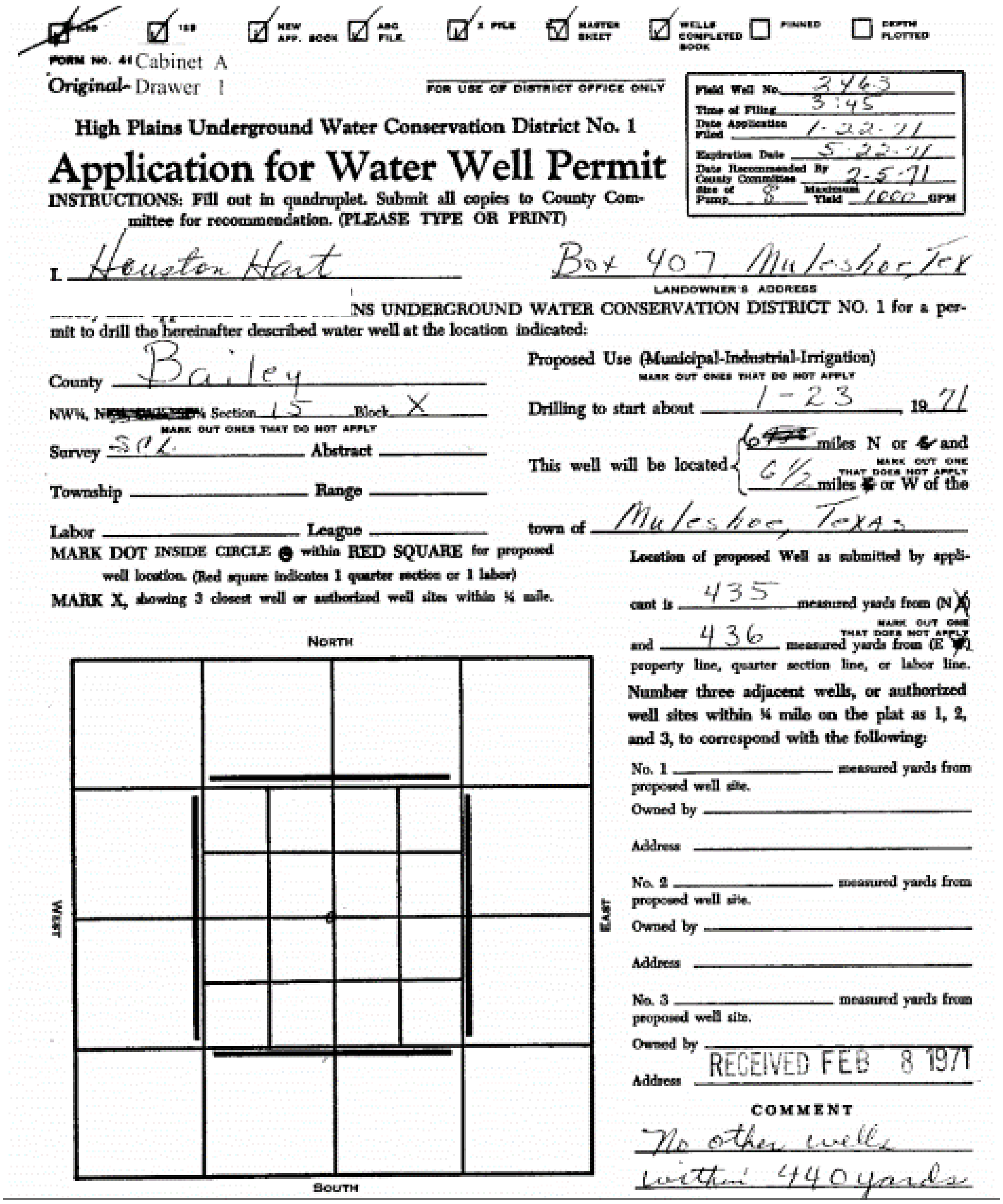


Source: The Cross Section 2012a.

Figure 19. Illustration of the concentration of center pivots and wells with permits in the High Plains Underground Water Conservation District (North-east of the District on the border with New Mexico)

Source: High Plains Underground Water Conservation District, http://atlas.hpwd.us/PermitLog.html (Accessed 27th January 2015).

Figure 20. Sample of an application for water well permit in the High Plains Underground Water Conservation District


FORM NO. 4 Cabinet A

Original- Drawer 1

FOR USE OF DISTRICT OFFICE ONLY

Field Well No. 2463
Time of Filing 3:45
Date Application Filed 1-22-71
Expiration Date 5-22-71
Date Recommended By County Committee 2-5-71
Size of Pump 8" Maximum Yield 1000 GPM

High Plains Underground Water Conservation District No. 1

Application for Water Well Permit

INSTRUCTIONS: Fill out in quadruplet. Submit all copies to County Committee for recommendation. (PLEASE TYPE OR PRINT)

I, Houston Hart Box 407 Muleshoe, Tex

LANDOWNER'S ADDRESS

NS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1 for a permit to drill the hereinafter described water well at the location indicated:

County Bailey

NW¼, Section 15 Block X

MARK OUT ONES THAT DO NOT APPLY

Survey SCL Abstract

Township Range

Labor League

MARK DOT INSIDE CIRCLE within RED SQUARE for proposed well location. (Red square indicates 1 quarter section or 1 labor)

MARK X, showing 3 closest well or authorized well sites within ¼ mile.

Proposed Use (Municipal-Industrial-Irrigation)

MARK OUT ONES THAT DO NOT APPLY

Drilling to start about 1-23 19 71

This well will be located 6 miles N or S and 6½ miles E or W of the town of Muleshoe, Texas

Location of proposed Well as submitted by applicant is 435 measured yards from (N S) and 436 measured yards from (E W) property line, quarter section line, or labor line.

Number three adjacent wells, or authorized well sites within ¼ mile on the plat as 1, 2, and 3, to correspond with the following:

No. 1 measured yards from proposed well site.
Owned by
Address

No. 2 measured yards from proposed well site.
Owned by
Address

No. 3 measured yards from proposed well site.
Owned by
Address

RECEIVED FEB 8 1971

COMMENT

No other wells within 440 yards

NORTH / SOUTH / EAST / WEST

Source: Source: High Plains Underground Water Conservation District, http://atlas.hpwd.us/Scans/Bailey/Bailey-02463.pdf (Accessed 27th January 2015).

4.5 Conflicts within the HPUWCD vis-à-vis the DFCs

DFCs can be contested by persons 'with legally defined interests' in groundwater in the management area. These can be done on the grounds that the DFCs have not been established reasonably. The Texas Commission on Environmental Quality can also be appealed to by persons considering "that a district has not adopted rules designed to achieve the desired future conditions or that a district is not enforcing compliance with their district rules" (Mace et al. 2008: 6). If the Commission accepts the petition and at the end the commission considers that the rules adopted by the district "are not designed to achieved the desired future conditions, the Commission may [...] dissolve the district's board and call for the election of a new board,

[…] dissolve the district, or (5) give recommendations to the legislature on how to achieve comprehensive management in the district" (Mace et al. 2008: 6).

The legislation also allows for GCDs to modify and revise the DFCs. These can be updated "at any time but at a minimum of once every five years" (Mace et al. 2008: 8). This leaves the door open to internal conflicts between different members of the GCD keener on groundwater conservation than others. It can also allow policy-makers to change policy direction and implement rules that "more reflect of present-day thoughts and realities" (TWDB 2016, pers. com.). This has already been seen in the High Plains Underground Water Conservation District. The imposition of pumping restrictions in July 2011 by the five-member board following the DFCs proved difficult, and in February 2012 the board had to respond to howls from farmers and issue a moratorium on enforcing well abstraction reporting requirements and pump restrictions (The Circle of Blue 2014),[61] as the GCD had gotten "ahead of its constituents on conservation goals" (TWDB 2016, pers. com.). In November 2012, members of the district challenged and managed to defeat "two long-term incumbents in a move [that] some directors and area producers connect with concerns about new district rules on reporting water usage" (Lubbock Avalanche-Journal 2013).[62] Later that year, two of the board members who voted in favor of the restrictions lost their re-election bids and two more resigned due to health and personal reasons (The Circle of Blue 2014).[63] In Lubbock, Texas, the dissatisfaction of many district members about the district rules "requiring users to install new water meters and report their usage to the district or face fines" was present. The race for election in the District has confronted proponents of a revision of the pumping limits pointing towards decreasing aquifer levels and the need to preserve the resource with opponents claiming that they are an infringement to private property rights "and a slippery slope toward socialism" (Lubbock Avalanche-Journal 2014a).[64] None of the challengers to the board approves of the district's new metering program Lubbock Avalanche-Journal 2014b)[65] and later in November 2013 the board voted to extend the moratorium (The Circle of Blue 2014).

5 The Edwards Aquifer, Central Texas

5.1 The Edwards Aquifer

The Edwards Aquifer (known also as the Edwards (Balcones Fault Zone) Aquifer) is a major aquifer in central Texas consisting primarily of a fractured and dissolved limestone creating a karstic and therefore highly permeable aquifer, one of the most productive aquifers in the USA

[61] The Circle of Blue 2014, "Texas and Kansas farmers take different paths to saving water", January 19th, 2014, http://www.circleofblue.org/waternews/2014/water_pollution/feature-stories/conservation-goals-ogallala-aquifer-run-legal-social-economic-challenges/ (Accessed 11th January 2016).

[62] Lubockonline.com, "Turnover continues on water district board, replacement sought", March 20th, 2013, http://lubbockonline.com/business/2013-03-20/turnover-continues-water-district-board-replacement-sought#.VMeAdzGUfzk (Accessed 27th January 2015).

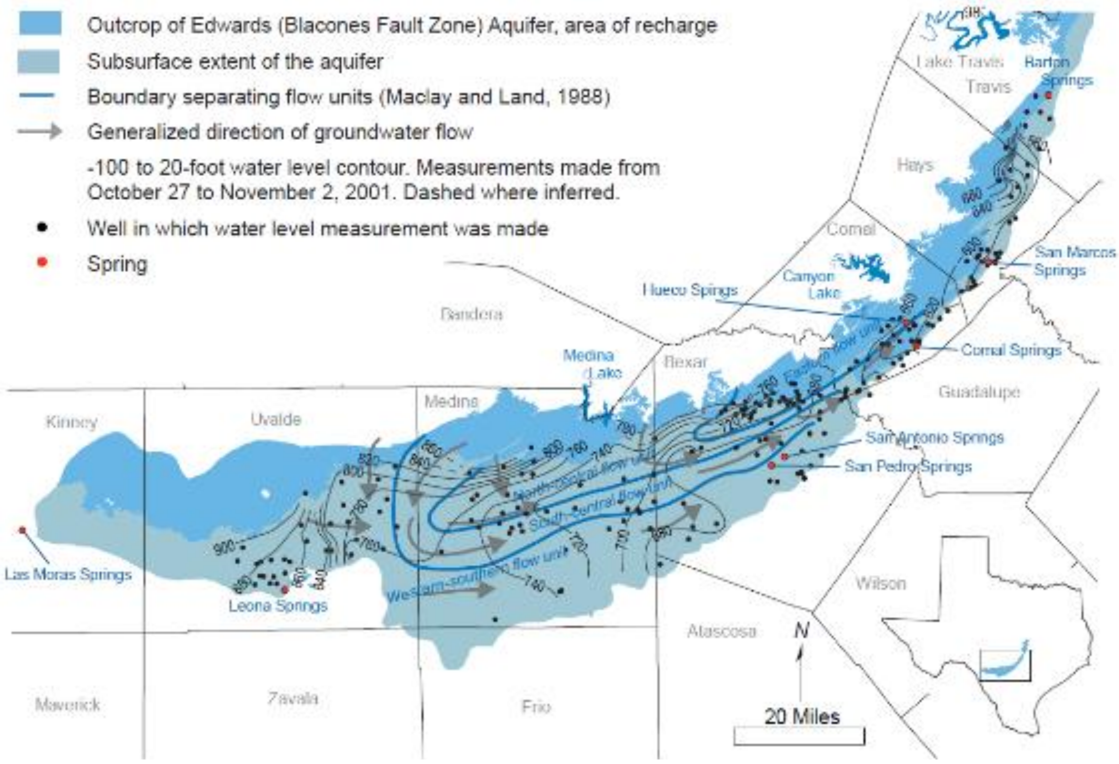
[63] The Circle of Blue, "Texas and Kansas farmers take different paths to saving water", January 19th, 2014, http://www.circleofblue.org/waternews/2014/water_pollution/feature-stories/conservation-goals-ogallala-aquifer-run-legal-social-economic-challenges/ (Accessed 11th January 2016).

[64] Lubockonline.com, "High Plains water board race could suggest changing views", November 3rd, 2014, http://lubbockonline.com/interact/blog-post/josie-musico/2014-11-03/high-plains-water-board-race-could-suggest-changing-views#.VMeAejGUfzk (Accessed 27th January 2015).

[65] Lubockonline.com, "High Plains water board challengers oppose metering rules", October 28th, 2014, http://lubbockonline.com/local-news/2014-10-28/high-plains-water-board-challengers-oppose-metering-rules#.VMeDqDGUfzk (Accessed 27th January 2015).

(George et al. 2011; Hamilton et al. 2006).[66] These limestone deposits are between 300 and 700 feet thick (90 to 200 meters) with freshwater reaching an average thickness of 170 meters in the southern part of the aquifer (George et al. 2011). Given the aquifer's high permeability, water bodies and water levels respond quickly to rainfall and can present rapid seasonal declines or hikes (ibid.). The Edwards Aquifer presents an outcrop area along the Balcones escarpment exposing the Edwards limestone at the surface (approximately 1,250 square miles) along the Texas Hill Country where part of its catchment and recharge area can be found (ibid.). The formation then descends south-eastwards towards the Gulf of Mexico, becoming confined, trapped between the Trinity formation underneath and clay, limestone, and chalk formations on top (George et al. 2011; Kuniansky and Ardis 2004).

Figure 21. Potentiometric surface and groundwater flow in the Edwards Aquifer.



Source: George et al. 2011.

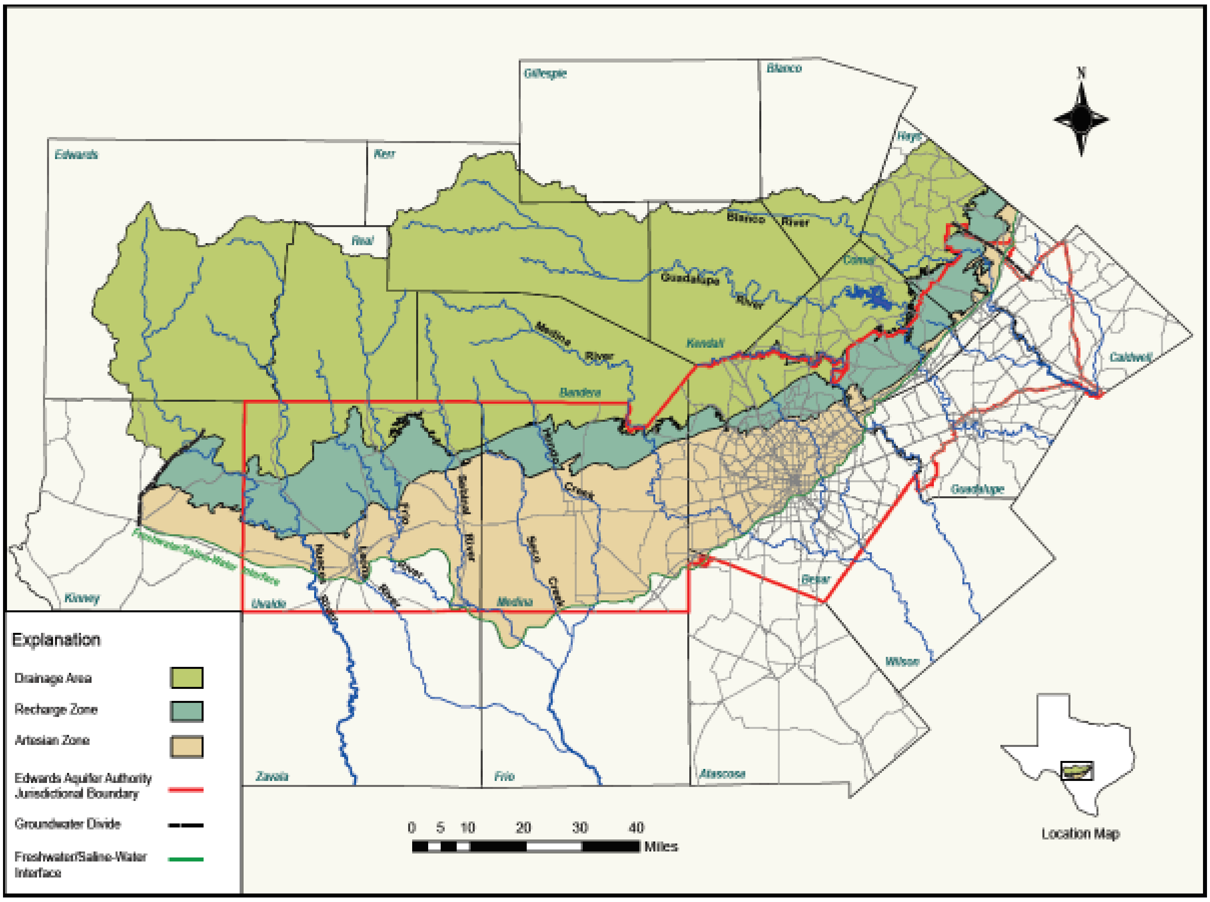
5.2 The Edwards Aquifer: an example of multi-layered groundwater governance

The case of the management of the Edwards Aquifer in Central Texas highlights the complexity and multi-level groundwater management in Texas across 8 different counties (Figure 22). The management of the aquifer by various organizations and agencies falls within different boundaries. The regulatory agency of the Edwards Aquifer does not follow the real aquifer boundaries as it only includes the main recharge area and the artesian zone and not the drainage area. The Edwards Aquifer Authority (EAA) spawned from the Edwards Underground Water District created in 1959. As a result of the stress caused by over-abstraction on the aquifer, a lawsuit in favor of the Sierra Club in 1991 against the US Fish and Wildlife Service for failing to enforce the Endangered Species Act and protect the species that depend on adequate flows in springs and rivers provoked the creation of the aquifer authority (Boadu et al. 2007;

[66] Of the three segments in the Edwards (Balcones Fault Zone) Aquifer, the one covered in this section is the Southern or San Antonio Segment. The other ones are the Northern Segment and the Barton Springs Segment.

Gulley 2015). As a result of the court ruling in favor of the Sierra Club, in May 1993, the Texas Legislature passed Senate Bill 1477 creating the Edwards Aquifer Authority, not only to preserve and protect the aquifer but also to avoid federal intervention (Dupnik 2012; Gulley 2015).

Figure 22. The Edwards Aquifer and the Edwards Aquifer Authority



Source: EAA 2015.

One of the reasons for the successful creation of the Edwards Aquifer Authority was that, after the court issued its decision in the Sierra Club case on February 1993, the ruling required the state to take action by May 31, 1993, otherwise there would be federal intervention in the matter (Gulley 2015). Senate Bill 1477, or the Edwards Aquifer Authority Act (the EAA Act), was historic, since it replaced the rule of capture with a use permit system to be used by the authority. The EAA Act required the EAA to issue permits on wells that do not meet exemption requirements, limit the total amount of groundwater withdrawals to 450,000 acre-feet per year (to be further reduced to 400,000 acre-feet over time), install meters on wells, and also require drought-time restrictions, including specific triggers and reduction amounts (Boadu et al. 2007; Charbeneau and Kreitler 2011).[67]

The control of withdrawals had been considered earlier during that legislative session (Legislature 73, 1993) in a draft piece of legislation, House Bill 1792. This bill called for the limitation of aquifer withdrawals and wanted to replace the Edwards Underground Water District with a new regional authority to manage the aquifer: the Edwards Aquifer Water

[67] Edwards Aquifer Authority, www.edwardsaquifer.org (Accessed 17th March 2014).

Resource Management Authority. With House Bill 1792 facing opposition from agricultural groups and irrigators, Senate Bill 1477 then appeared as a compromise, still with the agricultural groups against it. A solution however needed to be found for Senate Bill 1477 after the House Natural Resources Committee had amended the Senate Bill "to reflect the views of the agricultural and private property interests. The amended bill was passed out of the committee on May 17 and was passed by the House on May 24" (Gulley 2015: 52). A special conference committee was appointed when, on May 27th, the Senate rejected the amendments. In the end, the conference committee report was adopted on May 30, 1993, and the final bill was signed on May 31st (Gulley 2015).

As part of the EAA bill, an accommodation was granted to the agricultural interest when it was established that the cost of meters for all non-exempt wells would be paid by the new Authority (ibid.). The bill also gave the Authority its final name: the Edwards Aquifer Authority. The bill also established that withdrawal reductions in the Uvalde pool would be based on a certain index well (the Uvalde Underground Water Conservation District had remained throughout this process against the Bill) (ibid.).[68] The bill, as a concession, based the fees to be charged to irrigators "on the amount of water withdrawn at 20 percent of the fee charged to municipal and industrial users. By contrast, the fees for municipal and industrial users were to be based on the full amount of water that they were authorized to withdraw under their permits" (Gulley 2015: 53).

Groundwater users were required to apply for permits for future groundwater use and the Agency issued minimum annual pumping limits for users who could prove that they had been abstracting groundwater during the previous 21 years (Charbeneau and Kreitler 2011). Although the total pumping cap for the Edwards Aquifer was established in 2004 by the EAA at around 550 Mm3 per year in order to protect plant and animal species dependent on aquifer levels and spring outflow, 881 groundwater permits were issued by the Authority totaling 677 Mm3 of allowed groundwater abstraction per year (including under-utilized permanent water rights). As a result of such imbalance, the Texas Legislature raised the total allowed cap to 705 Mm3 in 2008, 5 percent higher than the maximum level of groundwater withdrawals registered in 1989, and required the recalculation of minimal spring flow requirements (Charbeneau and Kreitler 2011; Danielson 2015; Debaere et al. 2014). The process followed to grant these permits took a few years to resolve all contested permit cases (Danielson 2015). At the time, the EAA was aware that "the total amount of permits ultimately to be issued would exceed the 450,000 acre-foot cap, and was looking for ways to resolve this matter. Ultimately when faced with the deadline in the statute for the cap, the Texas Legislature raised it to 572,000 acre-feet" (ibid.).[69] Under this management system, new non-exempt wells (e.g. for municipal, industrial, or agricultural purposes) can be drilled into the Edwards Aquifer but a groundwater withdrawal permit from a user already holding a permit (from existing abstraction rights for lease or buy) needs to be obtained.

Additionally, the Legislature complemented its cap strategy of permanent volume abstracted with water allocations during drought periods, with a staged reduction of allowable withdrawals during drought episodes (Debaere et al. 2014). Reduction stages create however, new allocation

[68] See Figure 22 for the location of the Uvalde Underground Water Conservation District.

[69] According to Danielson (2016, pers. com.) "a 'pumping cap' of less than 572,000 acre-feet would probably have resulted in some reductions to some of the permits, and possibly some compensation being paid to off-set those reductions to achieve the resulting cap. This would have occurred outside of critical period management reductions that are required of permit holders during times of lower water levels or drought."

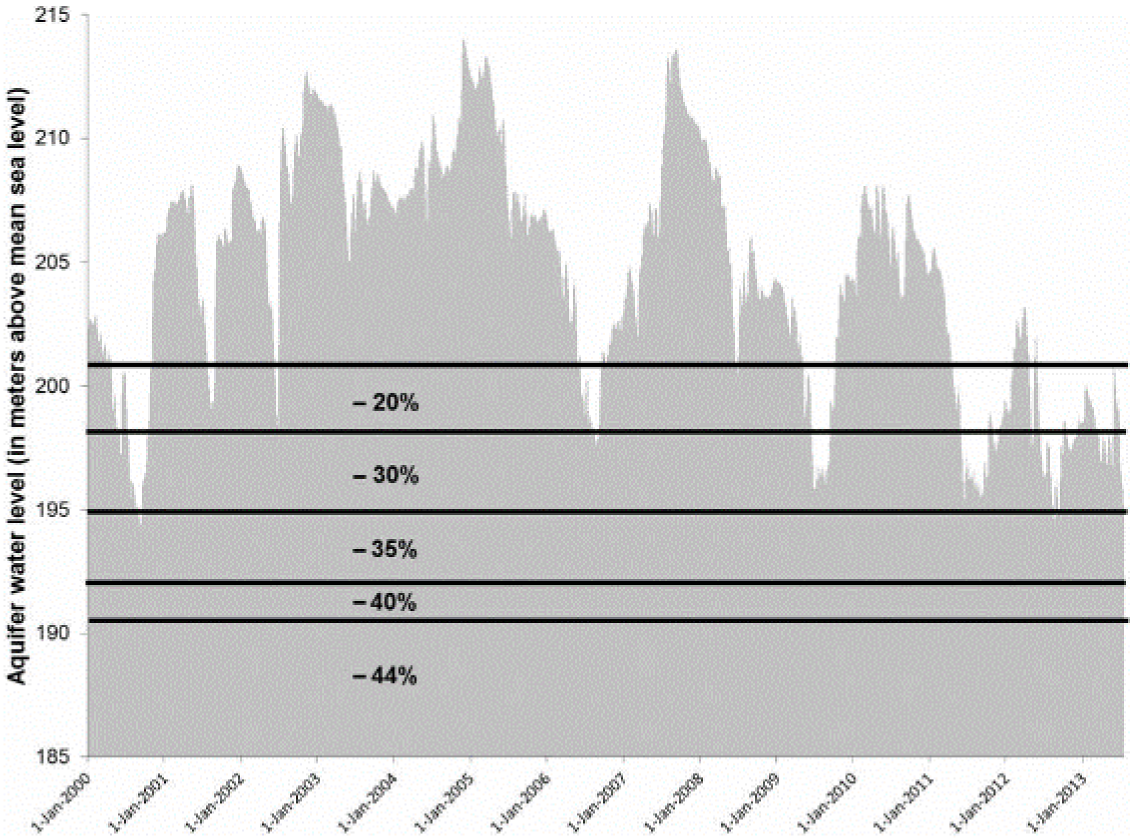
caps during droughts, triggered by target levels of spring flow at two major springs and aquifer levels in index wells (Table 3 and Figure 23) (ibid.). The regulatory system through thresholds linked to lowering aquifer levels became effective at the end of 2012 (ibid.).

Table 3. Regulatory thresholds for groundwater withdrawal reductions in the Edwards Aquifer during critical periods

Critical period stage	Comal springs flow (m^3/s)	San Marcos springs flow (m^3/s)	Index well level (meters, mean sea level)	Withdrawal reduction* (%)
I	<225	<96	<201	20
II	<200	<80	<198	30
III	<150		<195	35
IV	<100		<192	40
V**	<45		<190.5	44

Source: Debaere et al. 2014.

Figure 23. Aquifer levels and regulatory thresholds for the Edwards Aquifer



Source: Debaere et al. 2014.

The management and regulation of groundwater in the Edwards Aquifer is split between different agencies. The regulatory jurisdiction of the Texas Commission on Environmental Quality (TCEQ), the state's environmental regulatory agency in charge of protecting the state's public health and natural resources, only extends to the main recharge zone of the aquifer and is only concerned with water quality issues. There are also three regional water planning areas that also follow different administrative boundaries. These Regional Water Planning Areas depend on the Texas Water Development Board and they are in charge of administering and assisting in the development of the regional and state water plans. Their administrative and managerial activities include the provision of technical and administrative assistance to regional planning groups, water planning data collection, or managing regional planning contracts.[70]

The drought spreading across the Western USA in 2013-2014 has led managers of the Edwards Aquifer to consider new ways of preventing further groundwater deterioration. In September 2014, the Edwards Aquifer Authority asked central Texas farmers and ranchers to stop irrigating in exchange for a check, called the 'Voluntary Irrigation Suspension Program Option' (or VISPO).[71] This was part of the Habitat Conservation Plan triggered by the Endangered Species Act and providing various conservation measures to protect endangered species living in rivers with spring flows endangered by withdrawals from the aquifer. The enrollment to the VISPO program for irrigation permit holders happens prior to the time when reductions are required and "if water is enrolled in the VISPO and the VISPO is not triggered but some level of critical period water use reductions are required, then the water enrolled in the VISPO is subject to reductions" (Danielson 2016). When conditions to trigger the VISPO are met, irrigation users lose all access to the amount of water enrolled in the VISPO program "and they are also subject to the required critical period management water use reductions for the water they did not enrol in the program" (ibid.). This ultimately becomes, according to Danielson (2016) "a business decision that irrigation permit holders can evaluate anticipating commodity market conditions, weather conditions, and others, to decide what will work best for their personal circumstances."[72]

Under the Habitat Conservation Plan, the EAA is willing to pay 150 USD per acre foot (1,233 m3) from its budget for farmers to stop abstraction. In the past, the Authority has been already paying money (50 USD) to farmers 'just for agreeing to be on standby'. The goal of the Authority, which predicts the suspension of abstractions in 2015 if current conditions persist, is aiming to get 40,000 acre feet (49 Mm3) of groundwater enrolled in the program. The trigger for the program was set when aquifer levels reached 635 meters or below by October 1st, 2012 (EAA 2012).[73] Then, the EAA would notify the program participants to suspend the use of the enrolled groundwater for the following year, beginning on January the 1st. The program was envisaged for a duration of 10 years, "in order to provide maximum benefits in a repeat of the entire drought of record and to serve as a substantial component of in the Habitat Conservation Plan" for the Edwards Aquifer.[74] Users enrolled have the option to apply for a 5 year or a 10 year

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[70] Since 1997 Texas has had 16 planning groups, one for each regional water planning area. Each regional planning group is made up of about 20 members (representing a variety of interests including agriculture, industry, the public, municipalities, water districts, river authorities, water utilities, counties, groundwater users, etc.). Regional Water planning in Texas, http://www.twdb.state.tx.us/publications/shells/RegionalWaterPlanning.pdf (Accessed 17th March 2014).

[71] 'Edwards Aquifer offers cash in exchange for reduced irrigation', KVUE ABC, September 8th 2014, http://www.kvue.com/story/news/local/2014/09/08/edwards-aquifer-offers-cash-in-exchange-for-reduced-irrigation/15297653/ (Accessed 10th September 2014).

[72] This therefore creates a market for groundwater withdrawal permits and with certain limitations these permits can be transferred to another use or use within the EAA. For Danielson (2016, pers. com.), "the transaction is between the buyer and the seller. If an irrigation farmer in the EAA region increases the efficiency of his or her irrigation practices, and can use less water that water becomes water they can consider in selling or leasing to another user. With the implementation of the VISPO and ASR Leasing programs, irrigation farmers in the EAA can evaluate commodity market, weather and other conditions, and make business decisions about crop irrigation in current or coming planting seasons."

[73] Aquifer levels are monitored at Well J-17 on the San Antonio Pool - this well is located on a major flowpath, and it is used to trigger drought restrictions and pumping cutbacks, http://www.edwardsaquifer.net/intro.html (Accessed 25th January 2016).

[74] EAA n.d. VISPO White Paper, http://www.eahcp.org/files/minutes/03-17-11VISPOWhitePaper.pdf (Accessed 25th January 2016).

payment program (EAA 2012). The program for 2015 is currently full and the EAA no longer accepts VISPO enrolment.[75]

Table 4. Payment amounts for the VISPO Program, EAA

Option	Fee	1	2	3	4	5	6	7	8	9	10
5-Year	Stand-by*	50.00	50.75	51.26	51.77	52.29	N/A	N/A	N/A	N/A	N/A
	Implementation*	150.00	152.25	153.77	155.31	156.86	N/A	N/A	N/A	N/A	N/A
10-year	Stand-by	57.50	57.50	57.50	57.50	57.50	70.20	70.20	70.20	70.20	70.20
	Implementation	172.50	172.50	172.50	172.50	172.50	210.60	210.60	210.60	210.60	210.60

* The amount of the standby payment escalates at 1.5% compounded annually over the five years of the program.

Source: EAA, VISPO Summary, http://www.eahcp.org/files/uploads/2013-VISPO_summary.pdf (Accessed 25th January 2016).

The imposition of pumping restrictions under Stage 3 of the Critical Period Management Plan by the EAA that was in place during the 2015 drought was lifted in June 2015 in the Uvalde County area San Antonio area and in July 2015 for the Uvalde County area (who were under Stage 2 restrictions, requiring a reduction of 5 percent in pumping levels off their authorized amounts).[76] Given the lack of rain in the San Antonio Pool area[77] of the Edwards Aquifer, Stage 1 restrictions were imposed again in July 2015 for groundwater permit holders pumping more than three acre-feet annually, with the reduction of the authorized annual authorized pumping by 20 percent.[78] The final declaration of 'expiration of critical period management' for the San Antonio Pool of the Edwards Aquifer was issued by the General Manager of the EAA on the 10th of November 2015.

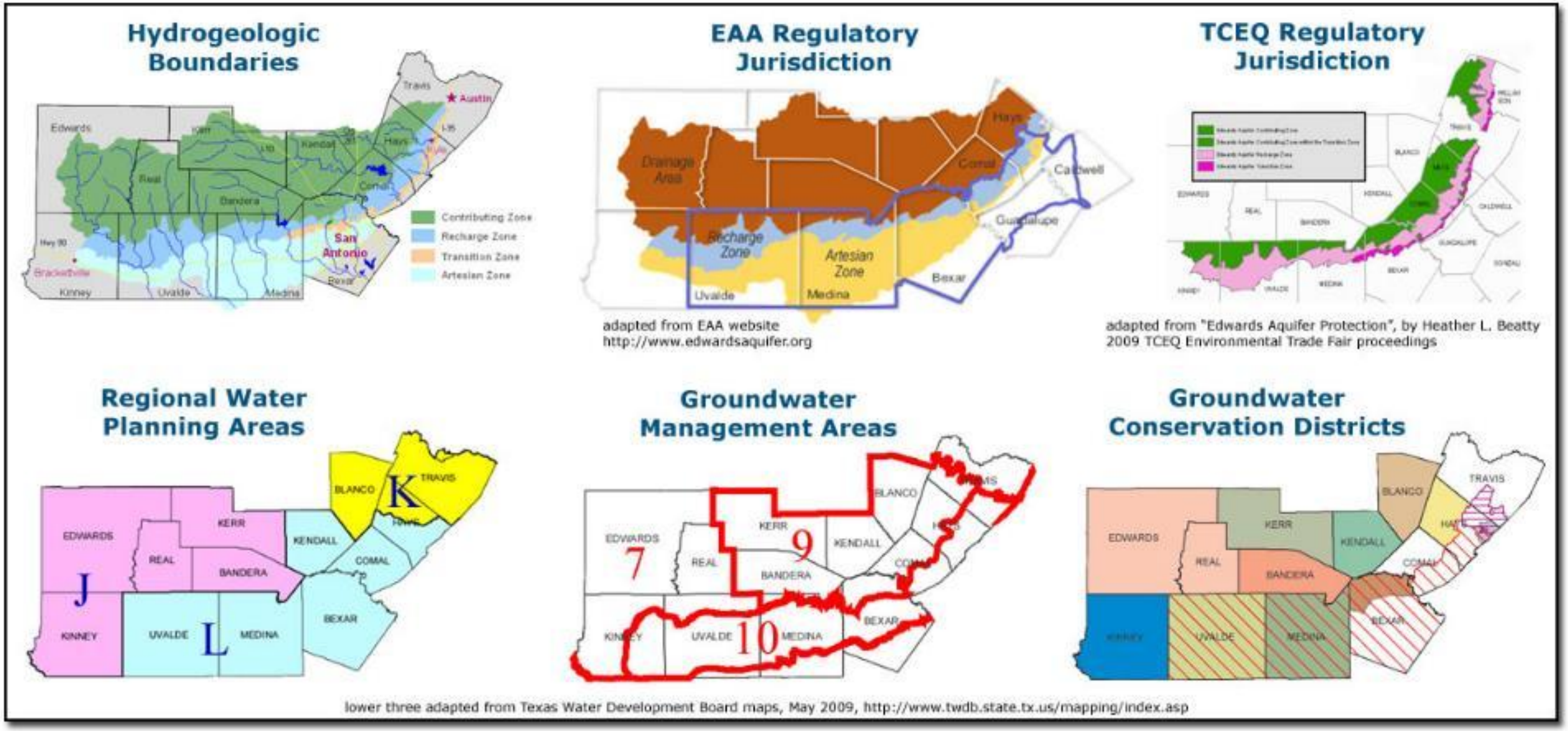
75 As of January 25th, 2016, according to the program's website (http://www.eahcp.org, Accessed 25th January 2016).

76 "EAA lifts all pumping reductions", Edwards Aquifer Authority, June 1, 2015, file:///C:/Users/ict/Downloads/stage-1-lifted-06-01-15.pdf (Accessed 25th January 2016); "Pumping restrictions lifted for Uvalde", Edwards Aquifer Authority, August 5, 2015, file:///C:/Users/ict/Downloads/Stage%202%20Lifted%20Uvalde%20080515.pdf (Accessed 25th January 2016).

77 The San Antonio Segment or Pool area is where most of the major natural springs occur. [This artesian area remains dry most of the year because of the large amounts of groundwater pumped by Bexar County users. NOT SURE WHAT THIS SENTENCE MEANS re: DRY. PERHAPS NOT FLOWING AT THE LAND SURFACE?] The San Antonio Pool is monitored by Well J-17, http://www.edwardsaquifer.net/intro.html (Accessed 25th January 2016).

78 "EAA declares Stage 1 pumping restrictions for users in San Antonio Pool", Edwards Aquifer Authority, July 30, 2015, file:///C:/Users/ict/Downloads/Stage%201%20073015.pdf (Accessed 25th January 2016).

Figure 24. The multiple layers of groundwater management for the Edwards Aquifer, Texas



Source: http://www.edwardsaquifer.net/rules.html (accessed 15th December 2013)

6 Energy and urban groundwater needs in Texas

Population increase and the urban and economic dynamics associated with it could affect the development and management of groundwater in the future. The Texas Data Centre and the Office of the State Demographer project a 71.5 percent increase in population between 2000 and 2040. It is expected that in 2040 Texas will have around 36 million residents. This increasing trend is shifting population pressure from rural areas to more and more concentrated and densely populated urban areas, or encroaching on peri-urban areas (previously rural). The political shifts associated with this urban and rural divide as more people move to the cities could change the geography and loci of power and main interests in groundwater from rural and agriculture dependent areas towards growing urban centers. Desalination is also being seriously contemplated as a supplementary resource for the urban areas near the Gulf of Mexico.[79]

Market forces can therefore shift water from rural to urban areas, "potentially causing clashes between landowners and districts. The combination of a nascent groundwater market and increased regulation by districts has already spawned litigation over how strictly districts may regulate groundwater" (Canseco 2008: 493). Additional and more recent dynamics affecting GCDs could however counteract this trend as the increasing need for water for the energy sector (oil and gas) is adding pressure to natural resources in rural areas. Legislators will have to continue balancing out the increasing demand for water in urban areas with the strategic economic interests associated with the energy sector in Texas and its demand for water.

6.1 The groundwater-energy nexus in Texas: oil and gas interests need water

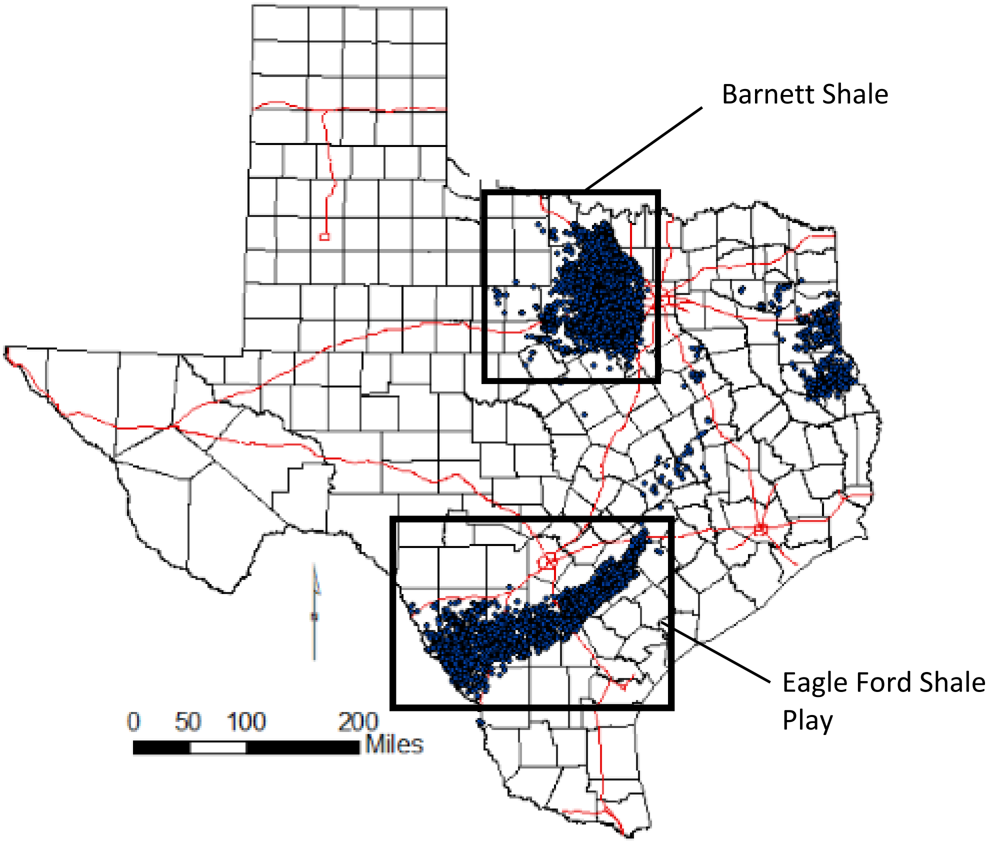
Surface and groundwater are used in Texas to produce energy. Thermoelectric power plants consume around 595 Mm3 of water per year, and they are responsible for an estimated 2.5 percent of the total water abstraction in Texas (2007 data) (Stillwell et al. 2011). Texas is the state that produces more energy in the USA, leading in oil and natural gas production. Even though water use for the extraction for oil, gas, coal, and other materials only represented 1.6 percent of Texas' water demand in 2010, this type of activity can have serious localized impacts amongst small communities (TWDB 2012a).

The sudden increase of hydraulic fracturing, or 'fracking', in the United States increased the country's capacity to produce onshore crude oil from 12 percent in 2008 to around 35 percent in 2012 (with projections to increase to 50 percent by 2019) (Scanlon et al. 2014). In 2004, oil and gas activities represented a mere 0.4 percent of the total groundwater use in Texas (Combs 2008). In Texas a number of counties have followed suit and increased their exploration activities, with two main areas standing out when it comes to the number of licenses for hydraulic fracturing: the Eagle Ford Play and the Barnett Shale areas (Figure 25). This shift was driven by a steady increase in oil prices, the availability of technology (horizontal wells) and the availability of water in these areas. However, the use of water for fracking is not well documented according to Nicot and Scanlon (2012). Their estimates suggested that, for instance in the Barnett Shale, 60 percent of water came from groundwater (with a variation of 45 to 100 percent depending on the county) (ibid.). Future estimates by Nicot and Scanlon (2012) project

[79] Desalination is also being contemplated as a potential future water supply in Texas and there have already been some attempts at desalinating brackish groundwater in Texas. In 2007, the city of El Paso opened a desalination plant to supply water from the mostly brackish Hueco Bolson aquifer in West Texas. The plant had a capacity to treat 27.5 million gallons of water per day to be supplied to the city of El Paso and a US Army base.

that the net water use for some counties will increase from 1 percent to up to 40 percent for the Barnett Shale area for instance and 5 to 89 percent for the Eagle Ford (2010 to 2050).

Figure 25. Concentration of hydraulic fracturing wells in Texas

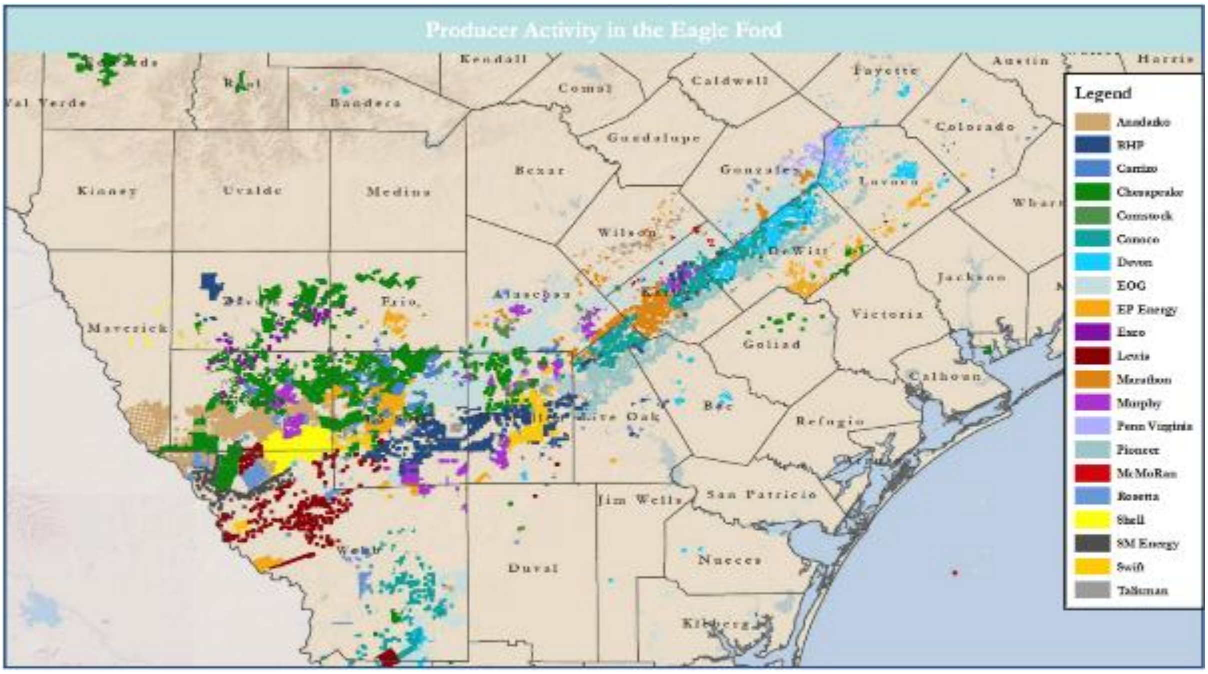


Source: Mullican 2014.

The Eagle Ford Shale covers 30 counties in Texas, with more than 200 operators tapping into shale reserves. Approximately 90 percent of the water needs for hydraulic fracturing comes from groundwater (Arnett et al. 2014). Over the past few years, gas and oil production increased in the Eagle Ford Shale, from 360 bpd (barrels per day) in 2008 to 339,000 bpd in 2012 and 8 MM cfpd (cubic feet per day) to 1,000 cfpd over the same period (ibid.). Energy production in the Eagle Ford Play is concentrated within a strip of 24,600 km2 and was ranked first in the USA for shale oil production in 2013 (Scanlon et al. 2014). Since surface water is not so abundant in East Texas, fracking activities have relied mostly on groundwater from the Carrizo aquifer (Nicot and Scanlon 2012). Scanlon et al. (2014) counted 8,301 fracking wells drilled between 2009 and 2013 with an average depth of 2 miles and lateral or horizontal depth of 1 mile, and using in total 150 Mm3 of water during these years (93 percent of this production was concentrated between 2011 and 2013). According to these authors there are around 100 shale oil operators in the area (Figure 26), but 6 of them represented 50 percent of the number of wells (ibid.). The amount of barrels of oil produced in the Eagle Ford play rose from 15,149 barrels in 2010 to over 800,000 per day in 2013 (Lyons and Tintera 2014).

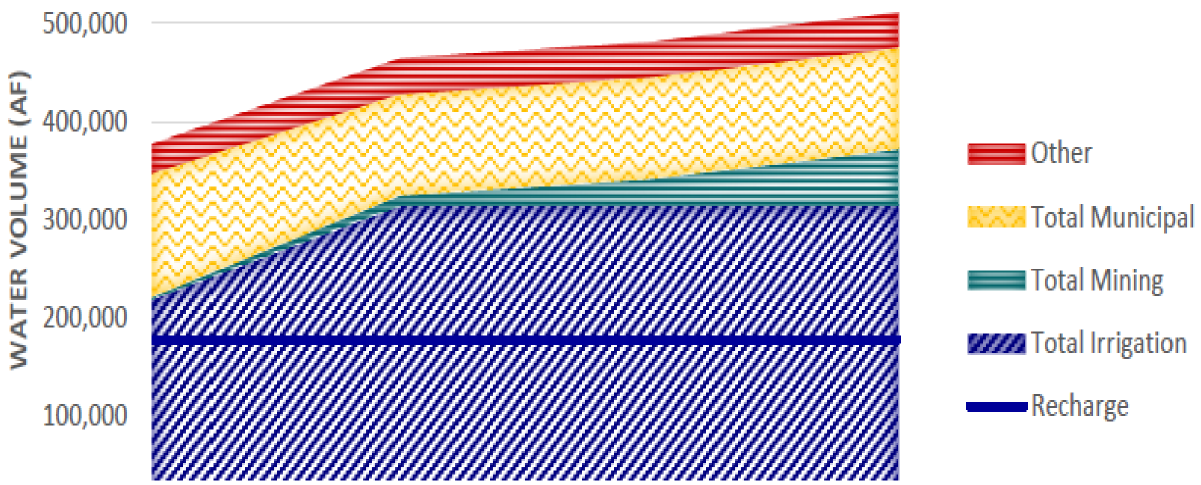
In terms of groundwater consumption, more than 500,000 acre-feet are consumed per year in the Eagle Ford, a volume that exceeds the estimated 300,000 acre-feet per year of aquifer recharge in the Carrizo-Wilcox aquifer (ibid.) (Figure 27). Groundwater used for hydraulic fracturing became the third largest consumer of groundwater in the area, with irrigation continuing to be the largest (the volume of groundwater abstracted for irrigation alone already exceeds the recharge rate by more than 50 percent) (ibid.). According to Nicot et al. (2012) from the Bureau of Economic Geology, University of Texas at Austin, the demand for water for hydraulic fracking will peak around 2020 and will diminish after that (Figure 28).

Figure 26. Oil and gas producers in the Eagle Ford Shale Play, Texas



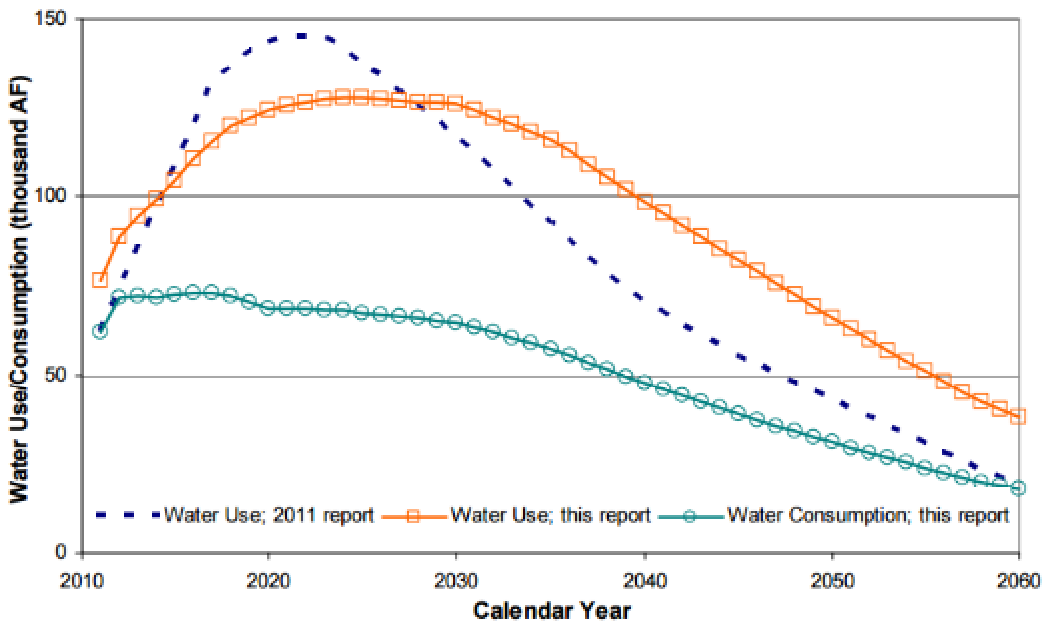
Source: FortressEnviroHoldings.com, http://fortressenviroholdings.com/wp-content/uploads/2015/07/Map-of-Oil-Gas-Producers-in-Eagle-Ford-Shale-Play-in-Texas.png (Accessed 8th December 2015).

Figure 27. Total Eagle Ford groundwater consumption and recharge



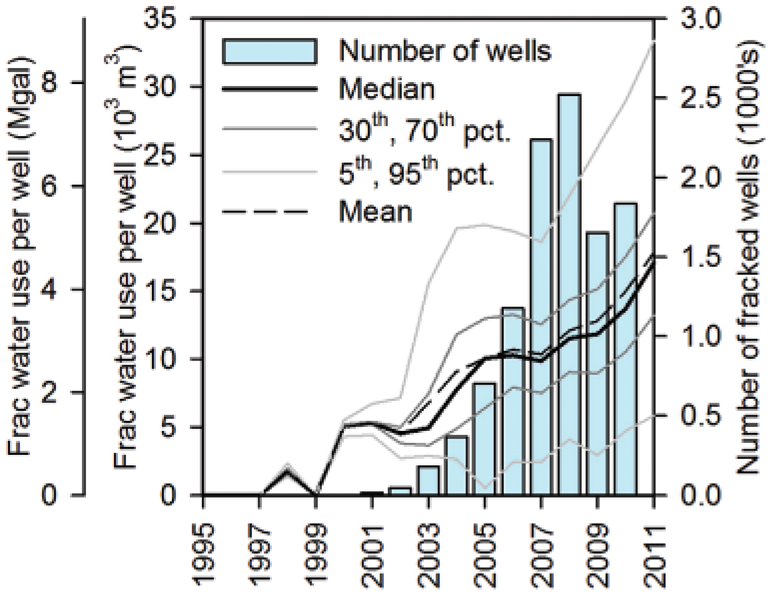
Source: Arnett et al. 2014.

Figure 28. State-level projections to 2060 for water use for hydraulic fracking



Source: Nicot et al. 2012.

Figure 29. Evolution of wells and water use in the Barnett Shale



Source: Nicot and Scanlon 2012.

In the Barnett Shale area, cumulative water use for hydraulic fracturing totaled 145 Mm3 between 2000 and mid-2011 (Nicot and Scanlon 2012). The Barnett Shale area has been producing gas since the 1990s, being the formation where horizontal drilling and fracking was pioneered (ibid.). This formation accounted for 66 percent of the total production of shale gas in the USA when it started being the sole producer in the early 2000s (ibid.). Productive wells are found in an area of around 30,000 km2 around Dallas at depths of 2 to 2.6 km (ibid.). Water consumption for hydraulic fracturing in the Barnett Shale area in 2010 represented 9 percent of the water use by the City of Dallas (ibid.). The abstraction capacity of the wells can range between 2,900 to 20,700 m3 per well per year (2010 data) and the number found is around 15,000 (ibid.). Average daily production of shale gas in the Barnett Shale was around 4.7 million cubic feet per day in 2013 (Lyons and Tintera 2014).

Scanlon et al. (2014: 12392) showed how water use for hydraulic fracturing "can vary markedly between plays [shale formations], such as in oil zones in the Eagle Ford" and that even though "the public perception is that there are huge water demands for HF [hydraulic fracturing], results from this study indicate that HF water use to oil production ratios (WORs) for unconventional oil production are within the lower range of those for conventional oil production, considering the well lifetime". Despite these results, the increase in water abstraction for hydraulic fracturing or other oil and gas production activities in groundwater rich areas where there is already a demand as it adds competition and additional pressure to the resource.[80] This could result in conflicts between the energy industry and agricultural or municipal water users in areas with stress and low water availability (or also in times of drought) (Harto et al. 2013). The increase in demand for domestic oil and gas production (in 2013 the

[80] The Environment Protection Agency has estimated that the amount of water needed typically to drill a shale gas well is between 7.6 and 19 million litres depending on the depth, horizontal length and number of times the well is fractured. Some of the fracking fluids (usually 99 percent water) used in the process returns to the surface (as flowback) after the fracturing procedure. Recovered fluids can range from 15 percent to 80 percent of the volume initially injected depending on the site. These liquids can be injected back into the ground, disposed of and discharged after treatment (Rahm 2011).

USA reached the peak of self-supply, with 84 percent of its oil and gas production generated within its borders) (Lyons and Tintera 2014) linked to the estimated increase in population during the next decades (TWDB 2012a) can potentially drive the prospection for new wells and generate additional conflicts between sectors and users.

Additionally, there are regulatory issues concerning fracking activities as there seems to be a loose fit between the current Water Code in Texas and the use of groundwater for fracking (Lashmet and Miller 2015). According to the Water Code, oil and gas exploration water wells are exempt from exploration permits according to Texas Water Code, which means that there is almost no impact of these activities on GCD's finances and therefore local groundwater user communities do not benefit directly from these activities (Lashmet and Miller 2015; Porter 2013). GCDs do not seem to agree on whether fracking should be classified as drilling, exploration, or production, "and consequently whether these wells are exempt from GCD requirements" (Lashmet and Miller 2015: 239).

Other issues related with fracking limitations in Texas have been explored by Fry et al. (2015) who found revenue and environmental inequalities affecting local citizens of municipalities having developed fracking wells. Their study of Denton, Dallas area, discovered how the largest share of the city's mineral wealth is controlled by absentee land and property owners living in the greater United States (29.7 percent of the appraised value that does not go to the operators themselves), more specifically a retirement community developer out of Arizona.

6.2 Groundwater transfers and urban supply in Texas

6.2.1 Groundwater supply and transfer projects in East Texas

The Metropolitan Water Company, established in 1999 for the purpose of developing groundwater resources in Texas and has been acquiring groundwater leases over the years in some of the most productive areas of the Carrizo-Wilcox Aquifer. The Metropolitan Water Company entered into an agreement with Blue Water Systems, the holder of the necessary permits from the Post Oak Savannah Groundwater Conservation District and a private company owning vested groundwater rights and delivering water supply to municipalities, utilities and other water providers in Texas (Figure 30). The Porters Branch Groundwater Project represents the first large scale groundwater lease[81] project in Texas and consists of two well fields in the Burleson and Milam Counties (both covered by the same GCD):[82]

[81] According to the Metropolitan Water Company website, the groundwater leases obtained are similar to an oil and gas lease and contain some of the following basic terms and conditions: "1. Bonus Payment - payable to the owner of the groundwater rights (most cases being the surface owner) when the lease is executed. This payment will maintain the lease in force and effect for the first year of the primary term; 2. Delay Rental Payment - paid each of the subsequent years during the primary term of the lease to delay the drilling of a well or wells. This payment will maintain the lease in force and effect for a one (1) year period; 3. Primary Term - this is the amount of time in which the lease can be maintained in full force and effect solely by the payment of bonus and delay rentals. The drilling of a well and the establishment of production will occur during this time frame. Once production has commenced, the leases will remain in full force and effect for so long as water is produced and royalties and/or shut-in royalties are paid to the landowners (Lessors).; 4. Royalty Payment - this is an amount paid to the surface owner for each acre foot of water produced on an annual basis; 5. Pooling - the pooling of tracts to create water units will be necessary due to the various sizes of tracts and to be able to abide by a particular groundwater conservation district's spacing requirements.; 6. Water Use - the groundwater leases allow landowners to continue to use water for their domestic and livestock watering purposes." http://www.metwater.com/landleases/index.html (Accessed 5th January 2016).

[82] Metropolitan Water Company L.P., http://www.metwater.com/about/index.html (Accessed 24th March 2015).

1) The 130 well field (Figure 30) having acquired 1,603 groundwater leases covering 20,000 acres of land with six well permits issued by the GCD delivering 20,000 acre feet per year of water to the Manor area of Travis County through a 53 mile long pipeline owned and operated by Cross Country Water Supply Corporation;

2) The Vista Ridge Well field (Figure 31) containing 1,312 groundwater leases[83] covering 50,000 acres of land. The leases have been assigned for 30 years and the project obtained permits for 18 wells from the GCD producing 50,993 acre feet of water per year and conveyed through a 142 mile long pipeline to the city of San Antonio.[84] Blue Water Systems associated itself with Abengoa, an international water infrastructure and construction company, as part of the consortium to finance, operate, and maintain production wells, pumping stations, water conveyance and storage tanks.[85] The project is expected to supply the growing demand for drinking water supply in San Antonio (with an annual growth rate of 1.8 percent) and enough to augment the city's water supply by 20 percent. The 30-year water purchase contract is worth 3.4 billion dollars and was passed unanimously by the City Council of San Antonio on the 30th of October 2014.[86]

In these cases, private water suppliers can use legal loopholes to develop groundwater transfers as long as there are willing sellers of groundwater rights. These cases are relevant as these are new issues that the GCDs and the state are facing when it comes to new challenges to groundwater management. Existing legislation is not fully adapted and the lack of rules can be used to further abstraction of groundwater. As part of the groundwater leases in the Vista Ridge Project, water that is transferred is not collected from the different wells but via a well field. The quantity extracted by the well field will be equivalent to the water rights on lease of the given area. In this case however, there are some inconsistencies and lack of clarity as to who is actually the owner of the groundwater leases, the Metropolitan Water Company or Blue Water Systems. As such, the Metropolitan Water Company is not mentioned in the Vista Ridge contract. In the contract it is stipulated that Blue Water Systems "has acquired certain lease rights which provide the lessee with groundwater resources" (Chubb 2014).

As seen in the Vista Ridge Project and Hay County, the mismatch between local legislation and the different layers of management and governance can have a severe impact on groundwater resources. Therefore, as it has been shown during the 84th Legislature (2015), the role of the central state is still relevant and decisive in those controversial cases where legislation is still not up to date with the reality on the ground. Legislative efforts need to catch up following the innovative and imaginative ways found by water suppliers and users in order to exploit the loopholes found in the system.

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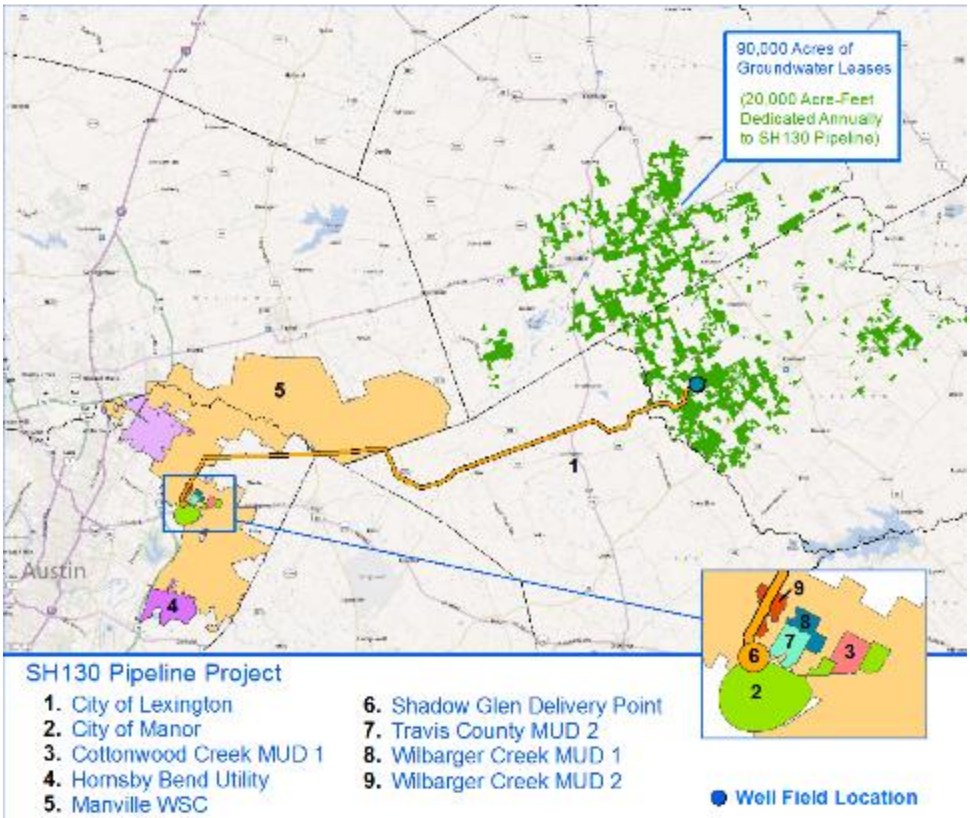
[83] Chubb (2014) has recalculated the number of lessees benefiting from this agreement, from an initial number of 1,809 listed as lessors for the Vista Ridge Project to an estimated 533 lessors receiving royalty payments from the project (1 percent of the total population of the Burleson and Milam Counties) even though the project will export 100 percent of the state-defined available groundwater from Carrizo-Wilcox aquifer for the two counties.

[84] The Post Oak Savannah Groundwater Conservation District made 1.39 million dollars in 2014, 1.06 million dollars in revenues in 2013 and 952,000 dollars in 2012 out of groundwater transport fees. Each request for groundwater transport has a fee of 6 cents per 1,000 gallons permitted plus an additional 100 USD administrative fee plus any additional staff time and-or necessary professional services (Post Oak Savannah Groundwater Conservation District, Statement of Revenues, Expenditures and Change in Net Position, http://www.posgcd.org/wp-content/uploads/2011/10/2013-Audit.pdf, Accessed 24th March 2015).

[85] Abengoa, "The Vista Ridge Consortium, led by Abengoa, to increase the water supply of San Antonio, TX", http://www.abengoa.com/web/en/noticias_y_publicaciones/noticias/historico/2014/10_octubre/abg_20141030.html (Accessed 24th March 2015).

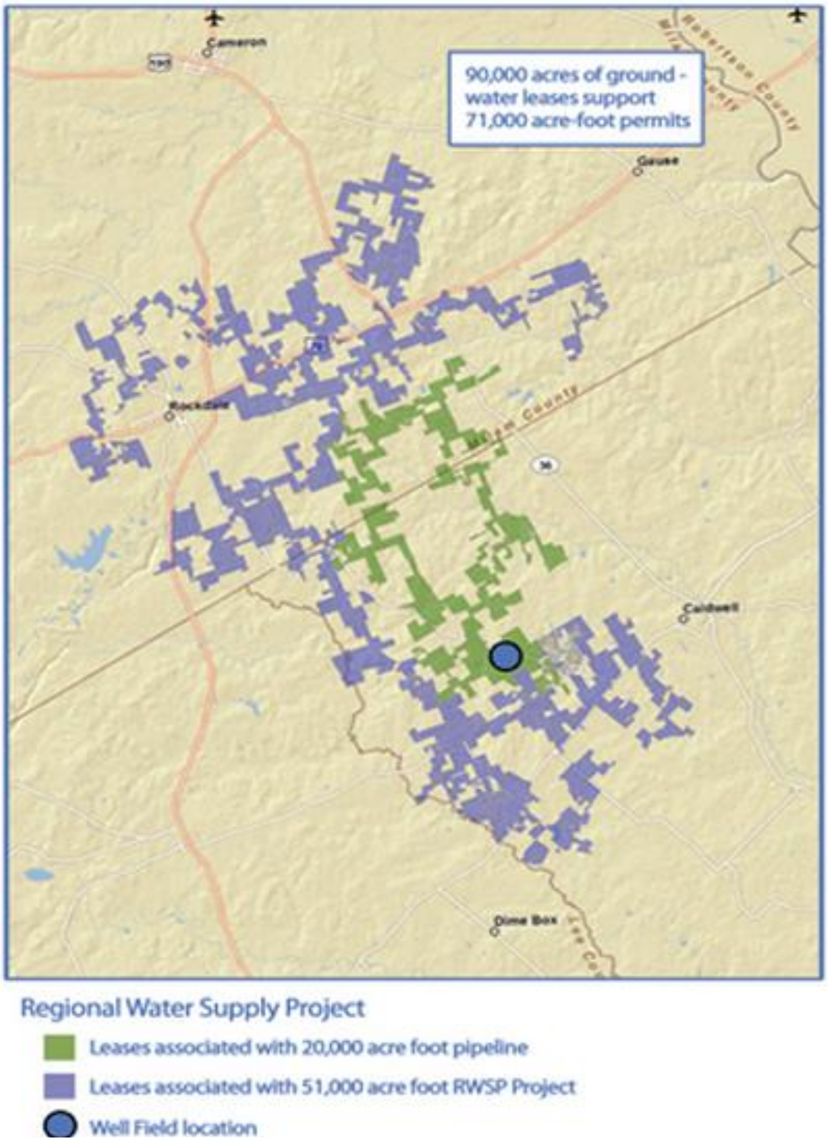
[86] Public Works Financing Newsletter, "$3.4-Billion water supply P3 with Abengoa OK'd in San Antonio", http://pwfinance.net/3-4-billion-water-supply-p3-with-abengoa-okd-in-san-antonio/ (Accessed 24th March 2015).

Figure 30. The 130 Well field and pipeline project for Travis County



Note: in green are represented the total amount of water leases owned by Blue Water Systems, 50,000 acres of which are for the Vista Ridge Project.
Source: Blue Water Systems, http://www.bluewatertx.com/wp-content/uploads/2012/09/SH130-Pipeline-Project.png (Accessed 24th of March 2015).

Figure 31. Groundwater leases in the Carrizo-Wilcox Aquifer



Note: in green are represented the land leases associated with the 20,000 acre foot pipeline; in purple are represented the land leases associated with the 51,000 acre foot transfer for the Vista Ridge Project; the blue dots represent the permitted locations of the wells.

Source: Blue Water Systems, http://www.bluewatertx.com/our-projects/bluewater-regional-water-supply-project-bwrsp/ (Accessed 24th March 2015).

6.2.2 Legal loopholes, groundwater transfers, and conflicts in Central Texas

Private ventures have exploited legal loopholes in order to pump groundwater from aquifers underlying 'white zones'. The Hays County Dispute was filed by a group of residents of Hays County facing groundwater depletion from a water transfer project implemented by Houston-based company Electro Purification. The project aims to pump 5 million gallons of groundwater per day from the Trinity Aquifer and sell it to the growing population of Austin's suburbs. The interest for Electro Purification for this project when it was conceived, was that the planned wellfield was in an area not regulated by any GCD. Even though the wells are pumping groundwater from the Trinity Aquifer and are located in the EAA's jurisdiction area, they pump groundwater from an underlying aquifer formation, not overseen by the EAA.[87] In this dispute, private water suppliers have been exploiting what they consider is their rightful access to the resource given the rule of capture existing in Texas, a move considered by others as a result of the still existing loopholes given the patchwork that is Texas' water regulation (Puig-Williams 2015).[88] This case exemplifies the risks within current legislation for GCDs as well as the fact that if these issues are not addressed properly, similar cases could arise in the future.

By finding areas where groundwater is not managed or regulated by a GCD, these private suppliers have been drilling well fields into the Trinity Aquifer in order to abstract, transport, and sell groundwater for urban and drinking supply. The geology of the area has allowed one company to drill through a thin section of the Edwards Aquifer and reach the Trinity Aquifer located underneath at lower depths. The hydro-stratigraphic area where drilling has been done does not belong to neither of the adjacent GCDs as the groundwater being pumped is unregulated and therefore is subject to the rule of capture. The company has therefore been able to claim pumping rights outside the reach of the Edwards Aquifer Authority (even if the area is within the administrative boundaries of the Authority, the water found underground does not belong to it as it is part of a different formation).

The company is planning to pump around 7.4 Mm3 of groundwater per year and sell it to other water-supply districts in the area (e.g. Buda District which expects to run out of water by 2017 or the expanding suburbs of Austin). This is over half the allowed amount of water determined by the Texas Water Development Board to be abstracted in order to reach the DFC established for the Hays-Trinity GCD (one of the neighboring districts) and 4 times the allowed abstraction for Barton Springs/Edward Conservation District (the other neighboring GCD) (Puig-Williams 2015). As a reaction, the Board of Directors of the Barton Springs/Edward Conservation District approved unanimously, and despite the burden on the GCD's finances (and the fact that it has to go through the Texas Legislature), on the 12th of March 2015 to expand the district's territory and include part of the unregulated area where the private water supplier is planning to pump.[89,90] Additionally, on the 24th of March 2015, a group of residents from Hays County associated as the 'Trinity Edwards Springs Protection Association' filed a law suit against the company drilling the wells, the Houston-based Electro Purification company, in order to prevent the company from abstracting groundwater. [91]

[87] http://www.texastribune.org/2015/01/23/hays-county-pumping-project/ (Accessed 5th January 2016).

[88] See also: Austin American-Statesman "Firm's plan to pump, sell water raises alarm in northern Hays County", January 20th, 2015, http://www.mystatesman.com/news/news/firms-plan-to-pump-sell-water-raises-alarm-in-nort/njsH9/?icmp=statesman_internallink_invitationbox_apr2013_statesmanstubtomystatesmanpremium#e0454ccd.3352564.735624 (Accessed 25th March 2015); The Texas Tribune "Groundwater wars brewing in Austin's suburbs" January the 23rd, 2015, https://www.texastribune.org/2015/01/23/hays-county-pumping-project/ (Accessed 25th March 2015).

[89] Hays Free Press, "BS/EACD Board expands jurisdiction", March 12th, 2015, (http://haysfreepress.com/content/bseacd-board-expands-jurisdiction, Accessed 25th March 2015).

[90] Hays Free Press, "Water plan under fire in Buda", January 29th, 2015 (http://haysfreepress.com/content/water-plan-under-fire-buda, Accessed 25th March 2015).

[91] The Texas Tribune, "Hays County residents sue commercial water driller", March 24th, 2015, (http://www.texastribune.org/2015/03/24/hays-county-residents-sue-commercial-water-driller/, Accessed 25th March 2015).

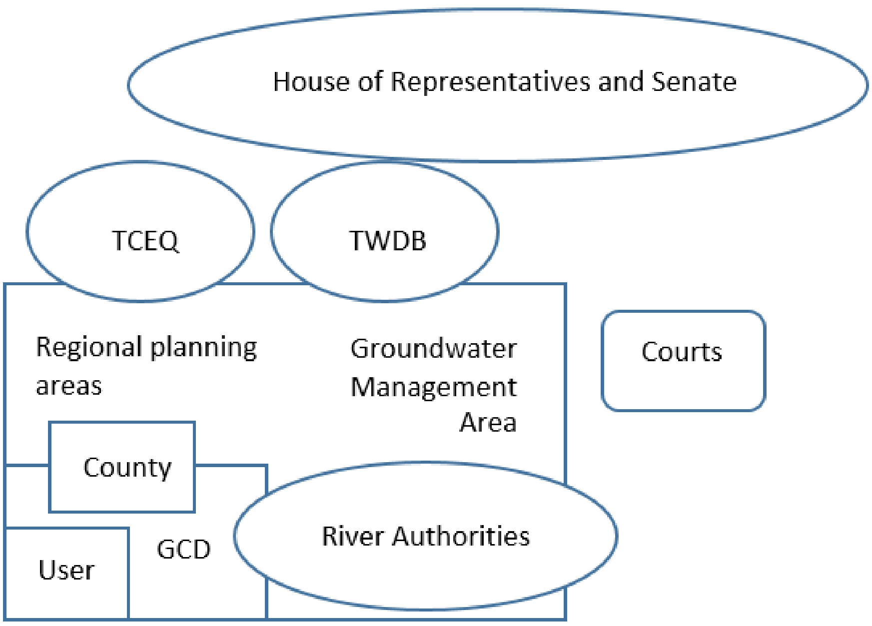
7 A multi-layered groundwater governance system in Texas

7.1 The different layers of groundwater governance in Texas

A review of groundwater governance in Texas depicts a complex and multi-layered patchwork of management and regulatory systems across different territorial and administrative scales (Figure 32 and Figure 33). From the user level to the legislative state level, groundwater governance permeates, and is enabled through these different layers. The smallest level of groundwater governance and in almost all instances, the basic form of groundwater governance in Texas, beyond the jurisdiction of the rule of capture that exists between users themselves, is the GCD. Because of Texas' decentralized political system, consensus is hard to find beyond county borders. The process by which enabling legislation is approved, remains a localized process and therefore counties remain a central part of this multi-layered governance system.

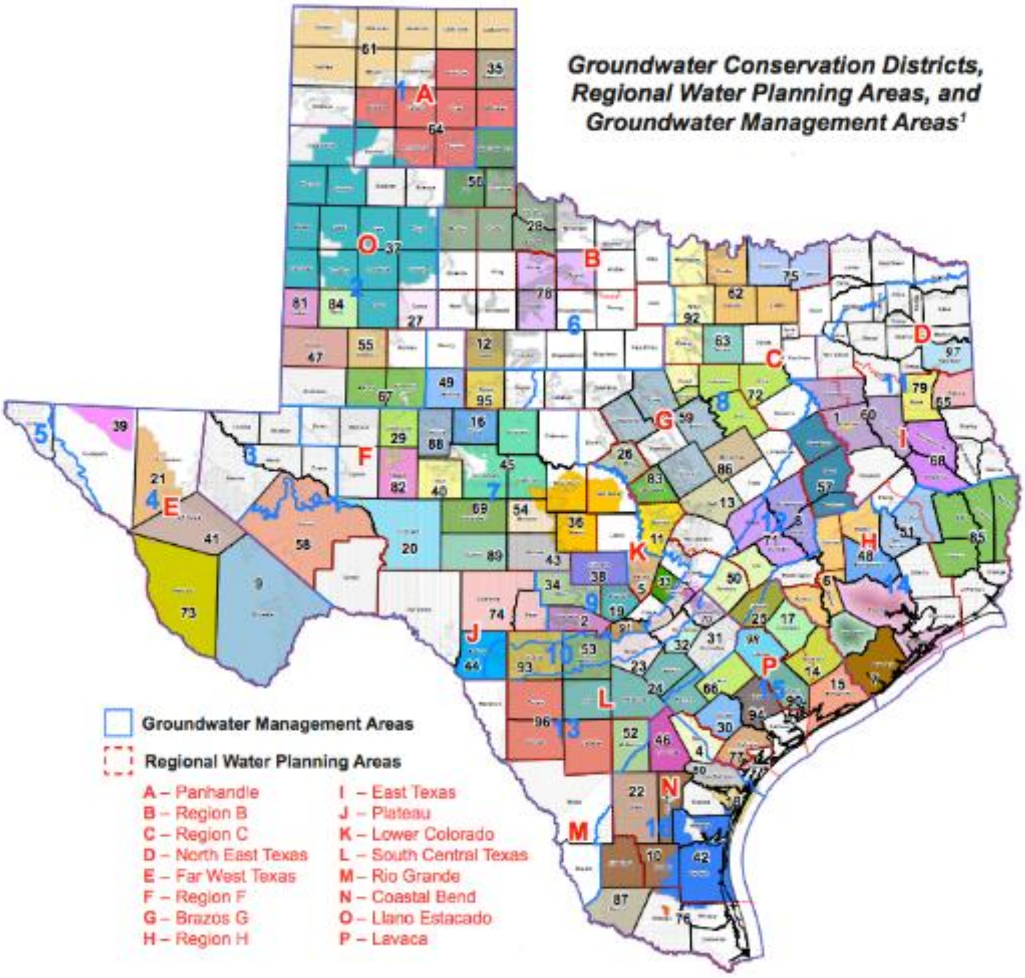
The supra-county level authorities dealing with surface water (TCEQ and River Authorities) can also impact groundwater management and some competencies can affect each other. However in terms of regulatory mechanisms GCDs are the only management tool with the legal legitimacy to regulate groundwater. They can also receive external funding in the form of grants and loans (e.g. from the Texas Water Development Board). The TWDB has until now held no regulatory authority for groundwater but has been financing GCDs through external funding with grants and loans. Courts have an external and limited role but can also, as seen before, have an impact and influence groundwater governance in Texas.

Figure 32. Multi-actor and multi-layered groundwater governance in Texas



Source: Authors.

Figure 33. A complex and multi-layered groundwater governance map of Texas



Source: Sunset Advisory Commission 2011c.

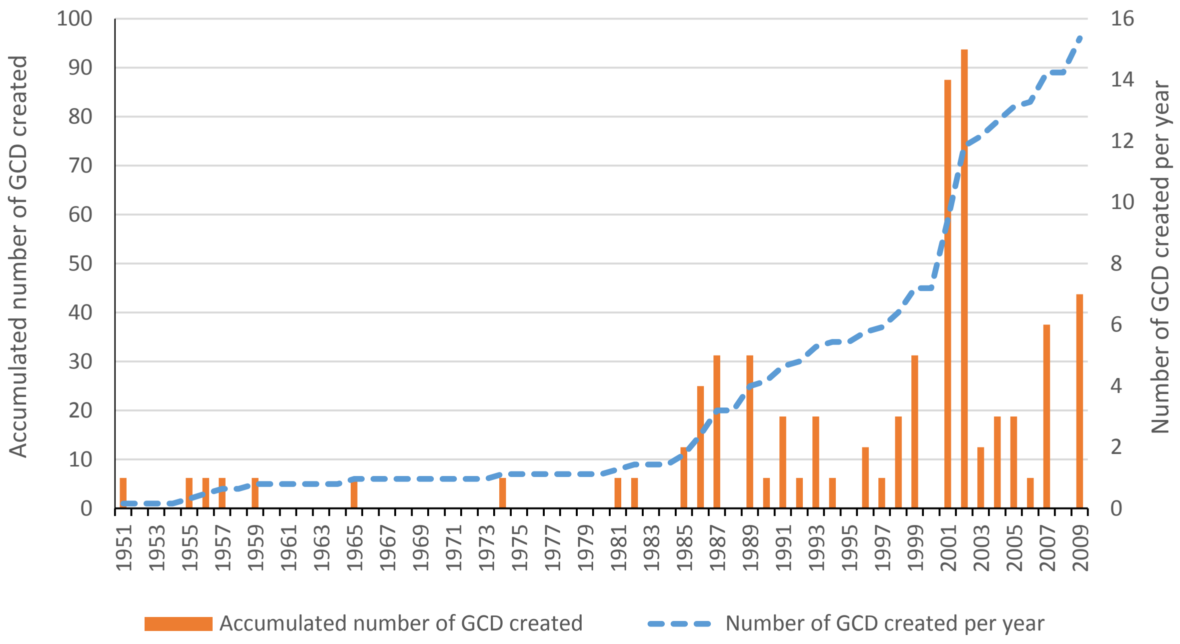
7.2 Rules and powers of GCDs

GCDs are at the center of groundwater management in Texas. A general review of the different GCDs in Texas depicts a slow pace of creation of GCDs since the first one in 1951 until the legislative sessions of 1999 and 2001 when the rate of creation increased substantially with 29 new districts created between 2001 and 2002 (Figure 34). The management reality of GCDs is however very diverse. Only 174 of the 254 counties in Texas are covered by a GCD and there are currently 99 GCD in Texas (97 confirmed).[92] There are 62 single-county GCDs and 37 containing more than one county. As Dupnik (2012) wrote, the increase in single-county GCDs responds to political choices despite the conflict between natural resource boundaries and administrative boundaries. According to this author, "the pattern stands in contrast to the earliest development of GCDs […] created from 1949 to 1984 […] configured along multi-county lines, primarily for the purpose of managing significant portions of major aquifers threatened by over-pumping" (Dupnik 2012: 27). The smallest GCD covers around 80 km2 and the largest one approximately covers 31,000 square kilometers. Even though on average GCDs have an average budget of over 676,000 USD per year and 3.7 full time employees for an average surface per

[92] Texas Water Development Board, http://www.twdb.texas.gov/groundwater/faq/ (Accessed 5th July 2015).

conservation district of 1,159,663 acres of land (Dupnik 2012), there are large disparities regarding funding, resources, and level of regulation exercised by GCDs across Texas.

Figure 34. Groundwater Conservation Districts created in Texas (1951-2009)



Source: Based on data from Dupnik 2012.

Many GCDs have faced tough rulemaking and management issues and lack of financial security (Brock and Sanger 2003). Many have low annual budgets as they can only rely on fees (well production fees, and administrative fees for well permits and export permits) and fines rather than a compulsory tax base. Revenues raised through taxes can vary between 20,000 USD per year for the smallest GCDs to over 2 million (Porter 2013). Some GCDs face significant funding challenges as they have statutorily restricted fee rates and low taxation rate (established relative to the value of the property of the well owner) (ibid.) and some GCDs cannot afford to open their offices every day. For Porter (2013: 65), many "voters express their keen desire to establish a GCD but are not willing to vote any amount of additional taxes for adequately funding the GCD." Revenues can also be raised via production but in some counties production is not sufficient.

In order to finance itself, a GCD must generate revenues, generally through property taxes collected from all residents within the district (calculated at a rate not exceeding 0.5 USD per 100 USD of assessed property values – currently set at 0.00754 USD) (Dupnik 2012) or from well production fees collected from major water users. Budgets for existing GCDs can range from under 100,000 USD for single-county districts with limited operational activities, to several million dollars for special districts with specific statutory groundwater management responsibilities or regional-scale GCDs. Production fees are capped at 1 USD per acre-foot/year for agricultural use, and 10 USD per acre-foot/year for other uses (Hunka 2008).

The level of achievement of the GCDs management plans and compliance with their statutory goals was reviewed by Texas' State Auditor in 2013 (SAO 2013). An audit of 23 GCDs on the achievement of their management plan goals found that 78 percent of the districts fully or partially achieved all applicable groundwater management plan goals (defined by the audit as: 1) providing the most efficient use of groundwater; 2) controlling and preventing groundwater waste; 3) addressing drought conditions; 4) addressing conservation). For the GCDs statutory requirements, the audit found out that 61 percent of the reviewed GCDs fully complied with 8 or more of the 10 Texas Water Code statutory requirements audited (e.g. obtaining surety bonds for employees and members of their board, obtain an annual financial audit, adopt annual budgets, hold quarterly board meetings, adopt policing and rules) (ibid.).

A large majority of GCDs have implemented rules regulating water quality and aquifer storage as well as establishing well inventories, well spacing, permits, and water conservation measures (e.g. the 50% aquifer level storage by 2050 rule in the High Plains Underground water conservation district) (Table 5). The definition of DFCs considered the spatial pattern of use. DFCs were set up by the Texas Water Development Board in conjunction with the GCDs in order to develop an acceptable distribution of pumping volumes (TWDB 2015, pers. com.). The establishment of the Desired Future Conditions generated 11 appeals in total across the state to the Texas Water Development Board. These came from 7 Groundwater Management Areas out of 16 (thus not all GMAs had petitions against the established DFCs). The type of petition according to a source from the TWDB (2015, pers. com.) varied, sometimes stating that the DFCs were too restrictive and some other times not restrictive enough.

Table 5. Groundwater Conservation District Activities in Texas

Type of activity	*Percentage of districts implementing such type of activity (%)*
Water quality monitoring and protection	73
Aquifer storage monitoring	86
Water well inventory	90
Well spacing permitting and construction	91
Education / public outreach	90
Water conservation	89
Waste oil recycling	0.02
Cooperative surface water program	70
Groundwater export rules	58
Grants and loan applications	32
Special projects and research	55

Source: Based on TCEQ 2011.

Other water conservation measures can include rules for regulating wasteful activities, water metering, developing drought management plans. Rules regulating water quality may include providing water sample collection, field analyses and laboratory services. Aquifer storage requires observation wells to monitor changes in groundwater storage. Well permits may involve specifically established district rules but most districts refer to the regulations established by the Texas Department of Licensing and Regulation’s Water Well Drillers Program (TCEQ 2011). It is relevant to mention that the Texas Water Development Board provides districts with the opportunity to take advantage of three-year loans to be used for initial expenses, low interest loans for users who purchase efficient or water conserving irrigation equipment and meters. In terms of application and use of this rule, 31 out of 97 confirmed districts currently offer this type of service.

Despite these rules, as Lesikar et al. (2002) pinpoints, GCDs are not obliged to have a well permitting program. Wells abstracting less than 25,000 gallons a day or to be used solely for domestic needs will be exempt. However, wells abstracting more than 25,000 gallons a day can be exempt "if the district's management plan includes rules allowing them" (Lesikar et al. 2002:18). Meters follow a similar case, as their installation "is a local option" (ibid.). Most GCDs do not require meters but "many consumers opt to install meters for business and management purposes" (ibid.).

The creation of GCDs does not reverse the Rule of Capture in Texas, but rather operates simultaneously. The way it is understood is that without the GCD, the protection of private rights is not possible. This is proven by the fact mentioned by Johnson (2013) that most GCD have actually been created through legislative action. The creation of Districts was not only a pre-emptive move to limit state control of groundwater and a compromise between conservation efforts and landowner demands (ibid.) but also a proactive empowering of local regulatory authority, arising as a trade-off between central regulation and local powers. It is in this duality of purpose where the balance between local interests and a need to regulate groundwater abstraction more cohesively at the central level resides.

Moreover, even if a GCD has been set up, the rule of capture still exists if the district does not regulate well spacing or set pumping limits (Lesikar et al. 2002). Even though the Texas Legislature through the Senate and the House of Representatives has the authority to regulate groundwater, no state agency can regulate groundwater production not associated with the 'underflow of a river' (ibid.). Thus, it can be argued that the existence of GCD does not counteract the rule of capture and users can always resort to use it whenever there is a conflict between rules and their private right to abstract water.

Also, even though GCDs have regulatory enforcement on 'point source' issues such as improper drilling, drought restrictions, illegal dump sites, or direct contamination, the enforcement of rules by the District is difficult as GCDs "do not have the financial capacity to adequately deal with the legal battles that face them" (GCD staff, 2014, pers. com.). Moreover, data on withdrawal levels is not very accurate, particularly for agriculture. This is due to the fact that most groundwater use in Texas is not metered (TWDB 2015, pers. comm.). Pumping volumes per se however are not "the vector for potential enforcement by the state, it's the DFC" (TWDB 2015, pers. com.) and the different measures established by each GCD to achieve the DFC.

Regarding the relationship between enforcement of rules and users' rights, groundwater users can sue or challenge the District Board if they feel that the GCD is either lowering the value of the property or over-regulating the use of groundwater (as seen in the Edwards Aquifer Authority vs. Day law suit, which established how far can conservation districts modify and regulate open access rule setting precedent for the San Antonio Fourth Court of Appeal ruling in 2013). Due to these law suits, GCDs take the risk to go bankrupt "or simply concede to the permit request" (GCD staff, 2014, pers. com.).

On that final point, a staff member interviewed from a GCD in Central Texas insists (ibid.):

"Groundwater Conservation Districts are mandated by law to establish DFCs (Desired Future Conditions) through regional cooperation, and are then allocated a MAG (modeled available groundwater), a number, or limit, by which they have to issue new permits and adjust existing permits. We are not allowed to over-allocate past our MAG, but individual landowners can sue us if they feel the amount we have permitted is too low. And because most Groundwater

Districts are not supported by taxes but fees (for example to permit a well or small violations), it means that they do not have the financial capacity to withstand the lawsuits. So they have a choice, either stand by their MAG and go bankrupt, or concede to landowner's desires/look the other way."

This means then, according to this source, that the permit system is real and enforced but due to the regulatory loophole, i.e. the lack of enforcement teeth, GCDs "do not have total enforceable regulatory authority" (ibid.). In that medium-sized GCD, the prevention of groundwater waste is enforced by issuing well permits. However, as the staff member of a GCD (ibid.) put it, well owners have a certain amount of immunity to centralized control of groundwater pumping due to Texas' basis of groundwater law on private property. Additionally, permitted wells can be required to submit meter updates to the TCEQ but this is based on the good will of users and the district, it would seem, does not check that recordings are actually accurate. According to the staff member, the submission of meter records is based "on an honor code". The District does not "go out and check that they are recording the true amount they are pumping." (ibid.).

New groundwater abstraction rules put in place to implement the DFCs can be met by opposition from some GCD members. Enforcement by the state of these rules can only happen if someone petitions the state to intervene because the GCD did not pass rules to achieve the DFC or is not enforcing such rules (TWDB 2015, pers. com.). In the High Plains Underground Water Conservation District, new DFCs were met by opposition from district members once the Board began passing rules to install water meters and reduce pumping. District members managed to get a new Board elected who then appointed a new general manager with, according to a source from the TWDB, "a very different viewpoint". It could be expected that the GCD will approve a new DFC which will be much more permissive.

7.3 Groundwater management and DFCs in Texas

7.3.1 The DFCs as 'managed depletion': leave for tomorrow what you cannot do today

The fact that DFCs are calculated based on existing groundwater storage and based on groundwater availability defined by groundwater districts (Hermitte et al. 2015), and not on safe yield or sustainable groundwater abstraction levels, would seem to suggest that groundwater over-abstraction is considered as the starting point or the norm from which the DFCs are derived. According to a source in the TWDB (2015, pers. com.), "long-term sustainability was not, in general, the main goal of the DFCs". The process of establishing DFCs "is not to control over-abstraction" and actually, "very few DFCs achieve sustainability" as the purpose of the DFC process was to "require GCDs to have a management goal […] and to collectively define that goal over a shared groundwater resource". This is "the norm, but it's not a specific choice of managing sustainably or not managing sustainably; it's more of a choice of political reality. If you don't have the support of the locals to pursue sustainability, then the odds are high that the boards will be voted out to go in a different direction."

As a member of a GCD put it, "[DFCs] are supposed to be a management tool not a hard cap" (Jeff Davis GCD 2015, pers. com.). Thus, as GCDs define their own limitations and abstraction levels, it is possible that current amounts of exempt and permitted use could be dangerously close to full allocation levels if it is assumed that users will make a full use of their allocations (as it happened in the Hays-Trinity GCD in 2011 where only with the exemptions for domestic and livestock, use represented almost the full allocation of groundwater in the district) (Porter

2014). As a member of the Bandera County River Authority and GCD put it, "DFCs can be used by a district to drain an aquifer" (BCRAGCD 2015, pers. com.).

The fact that disparate DFCs can exist for different neighboring GCDs as long as they are ‘reasonable’ and ‘physically possible’ is due to the fact that these have to reasonable only to the GCDs in the GMA, subject to a formal challenge that can go to court (TWDB 2016, pers. com.). Within their rationale, some GCDs will consider that it is ‘reasonable’ to pump groundwater and dry up the aquifer as there is enough for 300 years, and others will not (ibid.). In the end, the state "does not have a say in that; except in limited circumstances (protecting endangered species in the Edwards, minimizing land subsidence in the Houston area). The Legislature is, for the most part, silent on this, deferring to GCDs (created by the Legislature to deal with these issues)" (ibid.).

According to a report from the Natural Resource Commission from the Texas House of Representatives, "many GCDs and GMAs have adopted vastly different DFCs for the portion of the aquifer within their district. These different goals for the same aquifer have been approved by GMAs, resulting in widely divergent management goals and requirements in and over the same aquifer" (Texas House of Representatives 2014: 33). In the Panhandle area, in GMA 1,[93] some DFCs establish a remaining 40 percent of aquifer levels in 50 years. These are however aggregates as, for some counties, the reduction in aquifer levels in 50 years’ time is much more substantial. For example Dallam County in the Ogallala aquifer has set a DFC of 23 percent of remaining aquifer volume in 50 years’ time. This is due to the fact that this county is one of the counties that pumps the largest amount of groundwater for irrigation (up to 200,000 acre-feet per year on average between 1950 and 2000) (TWDB 2010) (Figure 35). Other counties have higher DFCs such as Hartley County with 40 percent left in 50 years or Armstrong County with 45 percent (ibid.) (Table 6). This ‘gerrymandering’ of aquifer boundaries, GCDs, and DFCs results in that some DFCs can be adopted at the aquifer level across a GMA (as a uniform average), or can be designated separately according to each subdivision of an aquifer, geologic strata, of geographic area overlying an aquifer (such as a GCD) (Sunset Advisory Commission 2011c). For example, the Joint Planning Committee for GMA 1 approved the initial DFCs in July 2009 for the Ogallala and Rita Blanca Aquifers, quoting the Texas Water Code and stating that it would have to consider "’the uses or conditions of an aquifer within the GMA that differ substantially from one area to another’ and may adopt different DFCs for different areas overlying an aquifer" (Resolution NO.2009-01) (TWDB 2009: 23).

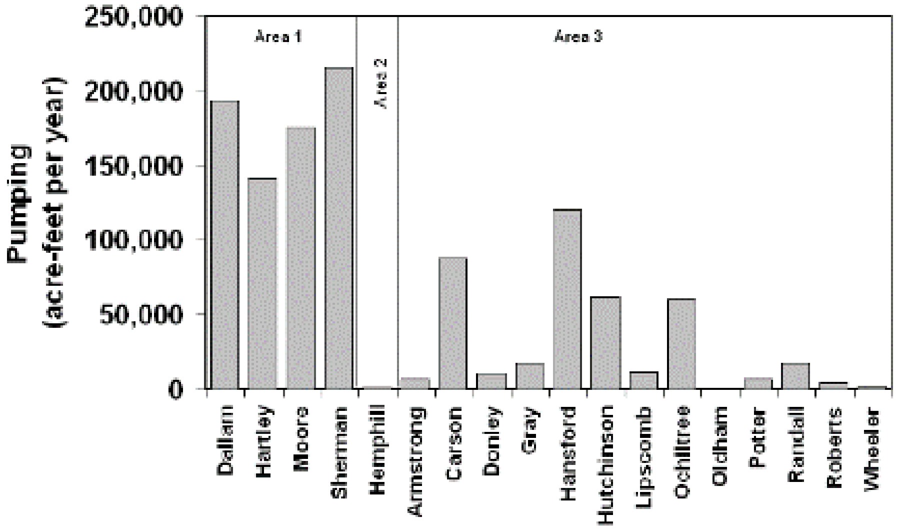
[93] GMA 1 consists of 3 different GCDs, the North Plains GCD, the Panhandle GCD, and the Hemphill County Underground Water Conservation District. One portion of the HPUWCD is within GMA 1 but it is managed in GMA 2 (to which the HPUWCD belongs).

Table 6. Summary of groundwater storage remaining after 50 years by area and county in GMA1

Area	County	Percent Volume Remaining After 50 Years by County	Percent Volume Remaining After 50 Years by Area	Percent Volume Remaining After 50 Years in Groundwater Management Area 1
1	Dallam	23	40	49
	Hartley	40		
	Moore	41		
	Sherman	57		
2	Hemphill	80	80	
3	Armstrong	45	50	
	Carson	48		
	Donley	49		
	Gray	46		
	Hansford	52		
	Hutchinson	44		
	Lipscomb	57		
	Ochiltree	49		
	Oldham	57		
	Potter	45		
	Randall	74		
	Roberts	50		
	Wheeler	52		

Source: TWDB 2010.

Figure 35. Average historic groundwater pumping from the Ogallala and Rita Blanca Aquifers in GMA 1 per county (1950-2000)



Source: TWDB 2010.

Given the fact that groundwater depletion already exists in parts of Texas (including the Panhandle area) (Neffendorf and Hopkins 2014), the passing of DFC rules by some GCDs would seem to indicate a de facto sanctioning of these existing groundwater abstraction levels taken as the norm from which future abstraction levels are derived. At the general level of the aquifer, as the percentage of change of existing groundwater supplies in Texas between 2010 and 2060 indicates, some aquifers do not present changes (Figure 36) (Hermitte et al. 2015). Thus, under this management regime, DFCs are essentially an escape forward for some GCDs, leaving serious management decisions for the future. This is again observable in the HPUWCD where the estimated total pumping levels projected into 2060 in the different model runs (GAM Runs) are delayed and changes phased out and reported for later years. The impending possibility that DFCs can be reviewed in the future by a new Board suggests that this situation is potentially unlikely to change, with irrigation maintaining the lion's share of water consumption in the years to come (Table 7). In West Texas, as a member of the Middle Pecos GCD put it, "business as usual has been working for us", "we are doing controlled mining" (Middle Pecos GCD 2015, pers. com.). For a source in the TWDB, "[t]here are some cases where DFCs have been set to honor current pumping levels and honor expected increases in pumping in the regional water plans" (TWDB 2015, pers. com.).

Another example of the potential effects of the DFCs on future groundwater resource management is brought by Hermitte et al. (2015), who compare the estimates of current groundwater use from the 2012 Texas State Water Plan and the DFCs in 2020. On a state-wide basis, groundwater availability for 2020 defined by GCDs is 55 percent higher than the total groundwater supplies in the regional water plans and 52 percent higher for 2060. Additionally, for all major aquifers, "groundwater availability defined by groundwater conservation districts exceeds total groundwater supplies" (Hermitte et al. 2015: 9).[94] This groundwater availability "is the total amount of groundwater, including both permitted and exempt uses, that can be produced from the aquifer in an average year that will achieve the desired future condition specified for the aquifer" (Hermitte et al. 2015: 12). It is interesting to mention that, according to Hermitte et al. (2015: 80-9) study, "in 74 counties, mostly located in the northern Panhandle, Far West Texas, and near the Gulf Coast, groundwater availabilities defined by the groundwater conservation districts were higher than those defined by the regional water planning groups by a total volume of 1,536,094 acre-feet."[95]

Based on this, one potential explanation for such overestimation between available groundwater quantities in the future and existing modeled groundwater supplies by GCDS could be the necessity or desire by some GCDs to establish a safety buffer volume to be transferred for future needs and used to maintain or potentially even increase abstractions by users. In essence, this results in GCDs reporting higher groundwater usage levels in the future in order to accommodate expected groundwater demands. Ultimately however, as Hermitte et al. (2015: 10) wrote, "there may be times when the state water plan is out of sync with more recent

[94] Groundwater availability is defined as "the amount of groundwater available for use as defined by policy decisions on how to manage groundwater production and the physical availability of an aquifer to give up water" (Hermitte et al. 2015: 7). Groundwater supply is defined as the "Maximum amount of groundwater available from existing sources for use during drought of record conditions that is physically, through existing infrastructure, and legally available for use" (Hermitte et al. 2015: 5). House Bill 1763 in 2005 established that Regional water planning groups have to use groundwater availability defined by GCDs. However, GCDs only defined a few DFCs in time to be included in the 2012 State Water Plan. As a result, Regional Water Planning Groups "continued to define most groundwater availabilities for the state's aquifers on their own" (ibid.). In 2015 however, with all DFCs adopted, "the current round of regional water planning is using groundwater availability numbers based on the district's desired future conditions" (ibid.). Since the State Water Plan is a 5 year plan, it is relevant to determine "the extent of differences between groundwater availability and total existing and future groundwater supply volumes from the 2011 regional water plans and the modelled available groundwater volumes generated through the desired future conditions process" (Hermitte et al. 2015: 7-8).

[95] Following Hermitte et al. (2015: 9), this should not impact the implementation of the 2012 State Water Plan as, for that to occur, "district-defined groundwater availability has to be lower than the sum of existing and new supplies of groundwater as defined in the plan, what we refer to here as *total groundwater supplies*."

decisions by groundwater conservation districts on groundwater availability. Ultimately, it's the local rules and regulations and how they reflect the desired future condition and modelled available groundwater, that control whether or not a project receives a permit or whether the water volume of a permit may be pumped, regardless of what is in the state water plan."

Table 7. Irrigation water demand in the five counties with higher groundwater demand in the HPUWCD

		2010	2020	2030	2040	2050	2060
Castro County	Irrigation water demand (Mm3)	575	553	532	511	492	473
	% irrigation of total water demand	98	97	97	97	96	96
Parmer County	Irrigation water demand (Mm3)	507	501	496	491	485	480
	% irrigation of total water demand	97	97	96	96	96	96
Lamb County	Irrigation water demand (Mm3)	448	430	414	398	382	368
	% irrigation of total water demand	94	93	92	91	89	87
Hale County	Irrigation water demand (Mm3)	438	423	409	396	383	370
	% irrigation of total water demand	96	96	96	96	95	95
Lubbock County	Irrigation water demand (Mm3)	282	266	251	237	224	211
	% irrigation of total water demand	78	76	75	73	72	70

Source: Based on data from HPUWCD 2014.

Figure 36. Existing groundwater supplies (in acre-feet per year)

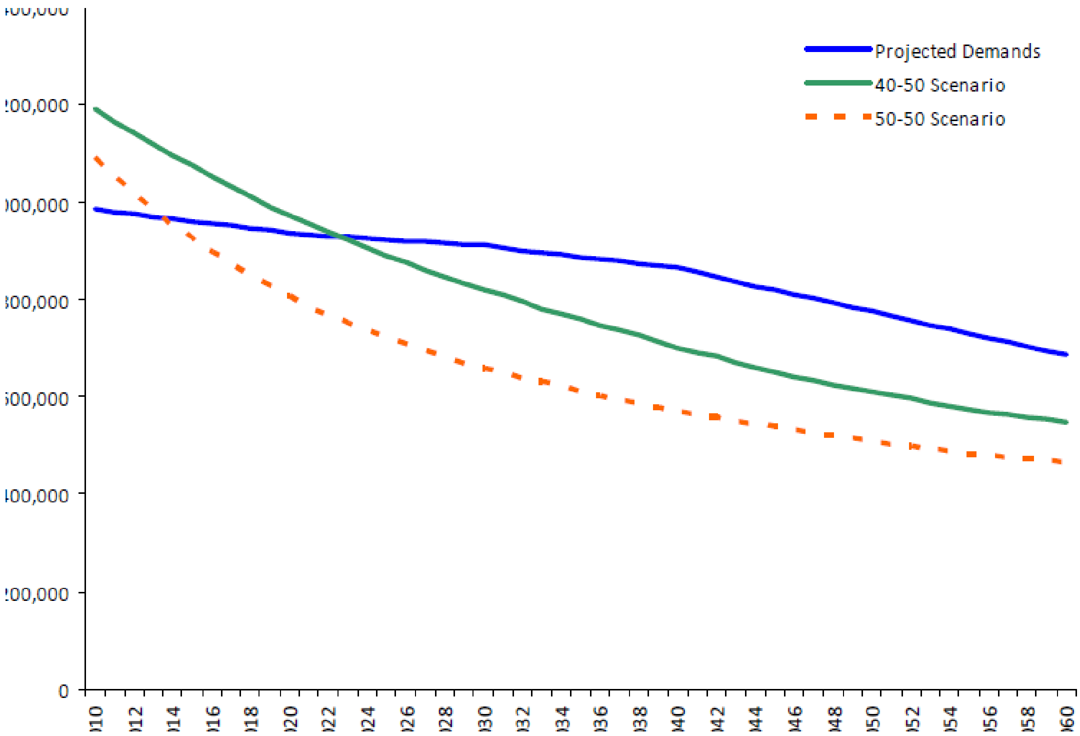
Aquifer	2010	2020	2030	2040	2050	2060	Percent Change*
Blaine	32,267	28,170	27,702	27,122	25,759	24,496	-24
Blossom	815	815	815	815	815	815	0
Bone Spring-Victorio Peak	63,000	63,000	63,000	63,000	63,000	63,000	0
Brazos River Alluvium	39,198	38,991	38,783	38,783	38,783	38,783	-1
Capitan Reef Complex	23,144	24,669	25,743	26,522	27,017	27,327	18
Carrizo-Wilcox	622,443	627,813	628,534	619,586	614,425	616,855	-1
Dockum	55,585	55,423	61,510	59,837	58,429	57,086	3
Edwards (Balcones Fault Zone)	338,778	338,702	338,828	338,794	338,775	338,763	0
Edwards-Trinity (High Plains)	4,160	3,580	2,802	2,335	2,065	2,065	-50
Edwards-Trinity (Plateau)	225,409	225,450	225,468	225,467	225,467	225,472	0
Ellenburger-San Saba	21,786	21,778	21,776	21,776	21,831	21,886	0
Gulf Coast	1,378,663	1,242,949	1,191,798	1,186,142	1,176,918	1,166,310	-15
Hickory	49,037	49,126	49,205	49,279	49,344	49,443	1
Hueco-Mesilla Bolson	131,826	131,826	131,826	131,826	131,826	131,826	0
Igneous	13,946	13,946	13,946	13,946	13,946	13,946	0
Lipan	42,523	42,523	42,523	42,523	42,523	42,523	0
Marathon	148	148	148	148	148	148	0
Marble Falls	13,498	13,498	13,498	13,498	13,498	13,522	0
Nacatoch	3,733	3,822	3,854	3,847	3,808	3,776	1
Ogallala and Rita Blanca	4,187,892	3,468,454	2,911,789	2,448,437	2,202,499	2,055,245	-51
Other	159,688	159,789	159,820	159,822	159,827	159,896	0
Pecos Valley	120,029	114,937	114,991	115,025	115,071	115,125	-4
Queen City	26,441	26,507	26,574	26,438	26,507	26,556	0
Rustler	2,469	2,469	2,469	2,469	2,469	2,469	0
Seymour	142,021	132,045	128,882	127,530	124,863	122,205	-14
Sparta	25,395	25,373	25,359	24,919	24,924	24,933	-2
Trinity	254,384	250,837	250,544	250,392	249,291	249,040	-2
West Texas Bolsons	52,804	52,804	52,804	52,804	52,804	52,804	0
Woodbine	34,173	34,036	33,932	33,876	33,741	33,688	-1
Yegua-Jackson	8,354	8,298	8,290	8,290	8,290	8,290	-1
Total	**8,073,609**	**7,201,778**	**6,597,213**	**6,115,248**	**5,848,663**	**5,688,293**	**-30**

Source: Hermitte et al. 2015.

7.3.2 Reduction scenarios and the reality at the local level

Returning to the example of GMA 1 in the Ogallala Aquifer, both the 50/50 scenario and the 40/50 scenario impose pumping limits which will require reductions in projected withdrawals. Following Figure 37, based on TWDB projections, under the 50/50 scenario water consumers would need to reduce withdrawals starting in 2014. Alternatively, the 40/50 scenario would require that reductions begin in 2023. By 2060, the projected total reduction of groundwater withdrawn would be 223,000 acre-feet under the 50/50 scenario and 142,000 acre-feet under the 40/50 scenario. Based also on these management scenarios, the fact that in some areas economically accessible groundwater already represents 50 percent of the total volume stored (such as in the High Plains), coupled with DFC set levels in some areas aiming for 50/50, results in an almost official ratification of the depletion of the aquifer (via the approval of the DFCs), leaving for tomorrow (i.e. the next generation) the arduous task of actually controlling and reducing groundwater abstraction in order to attain a sustainable abstraction regime for the aquifer. The revision of the petition related to GMA 1 by the TWDB, the Board ruled in favor of the GCDs and how they allocated the DFCs amongst themselves, and how they had "sliced and diced the DFCs" (TWDB 2016, pers. com.).

Figure 37. Projected pumping limits and total water demands for GMA 1, subdivision 1 (in acre-feet)



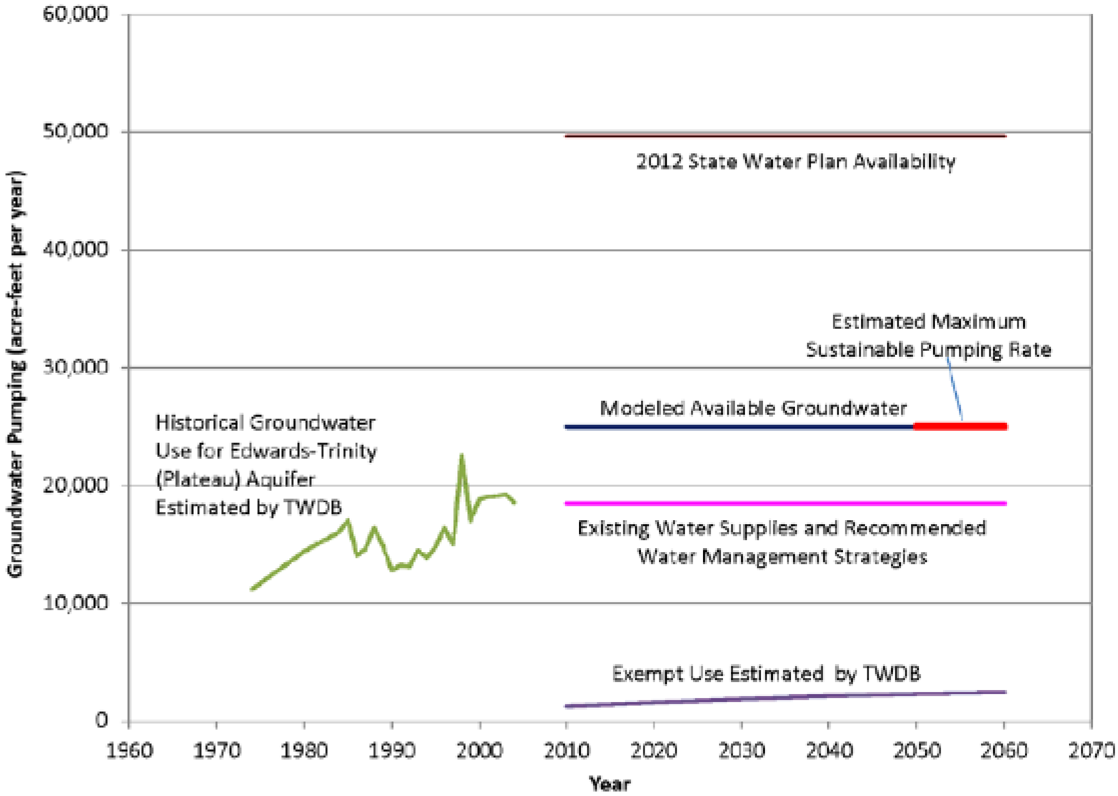
Source: TWDB 2010.

In GMA 9 for the Edwards-Group of the Edwards-Trinity Aquifer, calculations in 2009 by the TWDB had shown an estimated annual demand of 1.07 Mm3. With the established DFC, the maximum allowed volume to be pumped was set at 1.55 Mm3 of Managed Available Groundwater available for the following 50 years. This is groundwater to be available for future abstraction and to accommodate future exempt well completions, and maintain current average drawdown with a reduction in spring flow of 4 percent (GMA 9 Edwards Group 2010). As an example, in another aquifer in West Texas suggests, the total authorized volume to pump within GMA 3 for the Pecos Valley/Edwards Trinity Aquifer following the MAG, amounts to 151 Mm3 per year without compromising the DFC, whilst actual production in 2015 amounted to 106 Mm3 (Middle Pecos GCD 2015, pers. com.). This means that this GCD according to its approved DFCs has still 45 Mm3 of groundwater authorized to pump that is not using and that could be abstracted.

The conceptual issue of 'managed depletion' and the maintenance of the ‘pumping status quo’ can be visualized in Figure 38 for the case of Val Verde County. In this Figure it is possible to observe how the historical levels of groundwater use from the Edwards-Trinity Aquifer already match groundwater pumping levels recommended in the water management strategies. However, the threshold defined by the Modeled Available Groundwater and the Estimated Maximum Sustainable Pumping Rate remain higher than the existing levels of water supply. These were defined as per the DFCs for Val Verde at 1 foot of average drawdown over the 50-year planning cycle, which produced a value of 25,000 acre-feet per year of modeled groundwater abstraction volume. Average aquifer drawdowns simulated by the model vary from 0 feet to -37 feet, but still maintain the average of 7 feet drawdown for GMA 7 (TWDB 2012b).

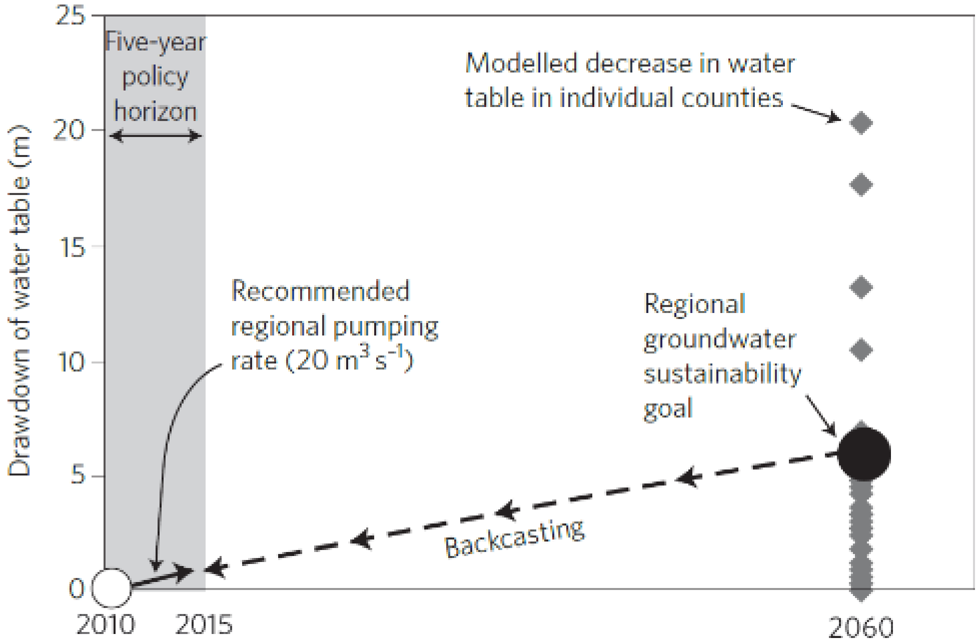
According to the TWDB (2012b), "this MAG is however approximately 6,500 acre-feet per year greater than the projected total current supplies and strategies to meet future needs estimated for Val Verde County of 18,471 acre-feet per year. The MAG, however, is less than the total available groundwater estimate identified in the 2012 State Water Plan of nearly 50,000 acre-feet per year. […] This leaves a margin between the MAG value and existing water supplies and recommended water management strategies of around 49,000 acre-feet per year." Hence, since the starting point used to define the DFC is a situation of over-abstraction, future abstraction levels set up at the GMA level validate these initial levels and limit only slightly future groundwater development, leaving margins for increase abstraction in the future. As a member of the TWDB said, "the status quo of non-sustainable development is baked into current thought of groundwater management in Texas" (TWDB 2015, pers. com.). These relationships and implications have been schematized by Aeschbach-Hertig and Gleeson (2012) and are shown in Figure 39.

Figure 38. Comparison of various groundwater planning amounts for the Edwards –Trinity aquifer in GMA 7 for Val Verde County



Note: the 2012 State Water plan addresses the state water needs for all water users, compiled from the approved regional water plans and approved every 5 years.
Source: TWDB 2012b.

Figure 39. Long-term goal setting for groundwater abstraction in Texas



Source: Aeschbach-Hertig and Gleeson 2012.

7.4 Two principles of groundwater management in Texas: private property and local rule

7.4.1 Groundwater and private property in Texas

The fugitive nature of property over water in Texas is exemplified by the changing property over water, from public for surface water to private for groundwater (Porter 2014). The separation between surface as public and groundwater as private causes extreme regulatory challenges as water remains in constant flow within the hydrological cycle. The separations, arbitrary definitions and limits to the public domain and control of water over private interests, have caused legislative and management bottlenecks over the years.

Senate Bill 332 enacted in 2011 enshrined private property over groundwater, by re-emphasizing the private nature of groundwater ownership in the Texas Water Code (section 36.002) by stating that "a landowner owns the groundwater below the surface of the landowner’s land as a real property" was voted 28 against 3 in the Senate, and 147 to 0 in the Texas House (Collins 2015: 458). This was further confirmed by the Texas Supreme Court in 2012 in the Edwards Aquifer Authority and the State of Texas vs. Burrell Day and Joel McDaniel, making clear that groundwater is owned by the surface landowner that the ownership interest is constitutionally protected by the State of Texas (ibid.).

According to Collins (2015: 453), the Day court ruling in Texas recognized "a 'groundwater' estate that affirms surface owners’ vested property interest in groundwater underlying" a tract of surface land whose owners have un-served groundwater rights. This ruling cemented the private ownership of groundwater, laying the foundations for increasing the economic value of groundwater as compensations were established for groundwater users whose rights had been limited by the Edwards Aquifer Authority.

Some farmers still view private property as sacred, putting forward a deep-seated uneasiness with groundwater control, viewing groundwater withdrawal restrictions and metering as "a real property rights violation" (Collings 2015: 470). These views reflect, according to Emels et al. (1992), the ideology of private property in Texas, enshrined by the legal system of private rights. Its legitimacy and understanding of its principles as 'common sense' have been consolidated through generations, shared history, and social relations. In the agriculture and ranching community, some will still share the views of farmer Maurice Rimkus, an Edwards Aquifer pumper who famously drove around with a bumper sticker which said "You Can Have My Water, Just Like You Can Have My Gun – When You Pry it Out Of My Cold Dead Hands" (ibid.). These views have caused that between 1986 and 2006, eleven petitions to create GCDs failed. A similar view was raised by the Corn Producers Association of Texas testifying in front of the House Committee on Natural Resources in June 2014: "the only thing we fear more than running out of water is increased regulation by the state" (Texas House of Representatives 2014: 29). This argument relies on the idea that no one has a greater stake in groundwater conservation than the direct users and that local regulation has been working for over six decades (Texas House of Representatives 2014). There is the fear that centralized state regulation will lead to one-size fits-all management rules, not taking into account local conditions (ibid.).[96]

7.4.2 Local rule vs. central push – GCDs and state control in Texas

Per se, GCDs are a community-based groundwater management tool and the Texas Legislature has taken a decentralized approach to groundwater protection when it referred to GCDs the management of the resource (Kaiser 2006). GCDs are seen by Brock and Sanger (2003) as an "essential component of the state's ability to protect the communities, agricultural and ranching operations, and the rivers and springs that depend on the state's nine major and 20 minor aquifers." However, even though GCDs are the "preferred method of determining, controlling, and managing groundwater" (Texas Water Code 36.0015) and considered "political subdivisions of the State of Texas" (Russell 2014: 1),[97],[98] they seem to be wedged between local concerns surrounding the interests of landowners and rural communities (empowered by the rule of capture) and the State of Texas' attempts to centralize water management and protect groundwater. As more GCDs implement and enforce production and abstraction limits through the DFCs, more landowners are adversely affected by these limitations and take their complaints to their legislators and representatives in the capital, or develop arguments against any type of control.

Even though the Texas Water Code (Chapter 36) gives GCDs a wide range of options to fund their mandate, GCDs are free to choose within their jurisdiction whatever rule they feel fit (some GCDs have no taxing authority and others have a lower than recommended ceiling for production fees). Legislators had to find an equilibrium between the respect of landowner rights and the need to manage and control groundwater over-abstraction in Texas. As Ellis (2007: 4) wrote, "[t]he concept of giving GCDs wide latitude in determining how, and how much to

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[96] Something that is already happening through the GMAs as even if GCDs have different rules based on individual needs, groundwater resource management is accomplished following state law (Texas House of Representatives 2014).

[97]" The Texas Constitution (Article XVI, Section 59b) states that GCDs "shall be governmental agencies and bodies politic and corporate with such powers of government and with the authority to exercise such rights, privileges and functions" (in Russell 2014: 1-2).

[98] A similar idea was already highlighted in 1984 by Kromm and White (1984) who studied the preferences to different types of adjustments or interventions amongst irrigators in Kansas' High Plains. Amongst the most popular ones were adjustments involving improved water use efficiency and amongst the least popular ones were financial incentives. Local groundwater management was the preferred level of management overall.

control production arguably makes good sense in Texas, a state with enormous variability in the distribution of groundwater and surface water supplies, population precipitation rates, economic uses", with great variety in precipitation, aquifer types, and water demands from these aquifers. For this author, the Legislature decided to avoid a 'one-size-fits-all' approach and reflected the commitment that the people closest to the resource "are the people best able to manage it" (ibid.).

GCDs can be affected by landowners' claims seeking to bend the rules, preserving their local interests and sustaining the self-limiting nature of the districts (Kaiser 2006), dependent on local politics, vested-interests, conflicts, lack of knowledge and resources. Thus, it is not the management instrument's fault (i.e. the GCD) but usually the users' fault that can distort the ultimate goal of GCDs. Texas landowners are sensitive to groundwater regulation (of any form) "because in some situations they feel groundwater district regulation encroaches on their private property rights" (Canseco 2008: 494). For Welles (2013: 493) this decentralized nature of groundwater management "leaves it vulnerable to capture by local interests that favor unsustainable pumping for short-economic gain." Even though GCDs keep struggling with the uneven enforcement of rules, "limited technical ability, and insufficient resources", given Texas's geographical variance in water needs and hydrologic structures, a decentralized water management system is likely to be "the only politically tenable groundwater management strategy in Texas" (ibid.).

GCDs have thus faced regulatory issues in the establishment of standards for groundwater sustainable use and its enforcement due to conflicts with users (Brock and Sanger (2003). The confirmation of a GCD is often dependent on "the area's political climate" and "well-funded opposition and general lack of understanding of the benefits of being a district are common culprits in confirmation election failures" (Brock and Sanger 2003: 6). The fear amongst users that the creation of a GCD would increase the cost of water, that it will represent the interference of the state, or that the GCD would interfere with private property rights have been used earlier to defeat the local proponents of GCDs (Brock and Sanger 2003).

Defendants of groundwater management at the local level rely however on the Open Meetings Act of Texas, adopted in 1967. This act ensures that 'the public's business is conducted in the open', aiming to make governmental decision-making accessible to the public and guarantee transparency for all government activities (Office of the Attorney General 2014). This act ensures public knowledge and participation as it requires that public meetings are given enough notice and publicity and have to happen at least quarterly. Since Groundwater Conservation Districts are public bodies governing groundwater resources, they are subject to this Act. As a member of the Jeff Davis GCD put it, the Open Meetings Act serves "to avoid corruption and keep everything transparent and accountable" (Jeff Davis GCD 2015, pers. com.). However, as Collins wrote (2015: 471), the core problem with GCDs and local control is that they do not fundamentally change the reality that groundwater remains governed by relatively weak local regulatory bodies that are at a very high risk of being captured by the local water consumers they are supposed to regulate."

The rural-driven and private property-centered view has been governing groundwater law in Texas until now (Collins 2015). However, urban concentration and population increase in cities could very well change this dynamic in the future. For its proponents however, local management continues to serve as a counter-power to the centralizing push of the capital and the narrative of slow bureaucracy in Austin reinforces the argument for local district management as being more efficient.[99] According to a member of the Jeff Davis GCD, "Powerful people do not want local control, they have more access to the State of Texas than at the local level" (Jeff Davis GCD 2015, pers. com.). To sum it up, "Decentralized system is the only thing standing in the way between rural areas and the urban areas sucking in all the people, votes, and water" (ibid.). Stronger asseverations however have been issued by a member of the Middle Pecos GCD (2015, pers. com.) regarding state control, when it was said "defend water management and keep it at the local level" and "keep the state out of our business".

Concerning the rule of capture, GCDs can represent an additional level of protection vis-à-vis this principle and the pull of growing urban areas and the continuous search for more water resources which comes alongside population growth.[100] "The capture rule provides little protection for rural areas when municipalities seek groundwater to export to their city. In response to these state-wide problems, the Texas legislature has turned to local groundwater conservation districts and asked them to develop and implement solutions to these problems" (Kaiser 2006: 485).

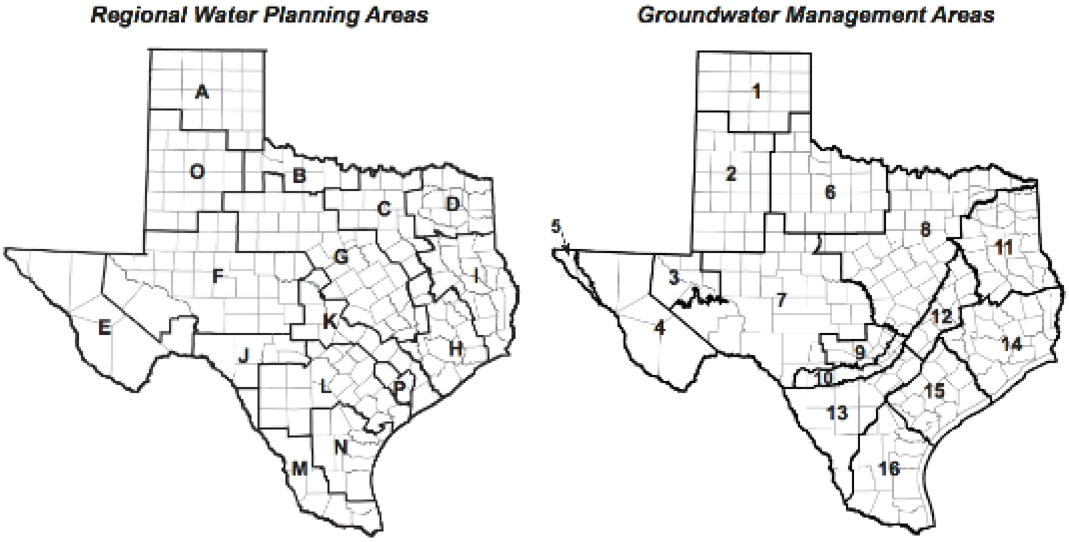
7.5 Management and administrative fit: central rule vs. local boundaries

A lack of overlap between the boundaries of regional water planning areas (there are 16) from the TWDB and the Groundwater Management Areas (there are also 16) causes planning and administrative imbroglios and complications (Figure 40). As seen before, GMAs were created to "better outline the 'pool' of groundwater in the overall area and to help generate groundwater policies that considered the shared groundwater sources among the GCDs" (Porter 2014: 84). The TWDB delineated regional water planning process based on factors such as river basins, water utility development patterns, political boundaries, socioeconomic characteristics, and public comment (Sunset Advisory Commission 2011c). Then, the Regional Water Planning Groups develop planning strategies to ensure that available water resources meet water demands over a 50-year planning horizon. GMAs are designated areas following the boundaries of GCDs and are used to promote joint planning for groundwater use. They have been defined as collective groups of GCDs and based on major aquifer boundaries (ibid.).

[99] The fact that during every legislative session the state representatives are flooded by work re-emphasizes this view. According to a member of the Jeff Davis GCD, legislators had during this session 6,000 proposed laws, they rely on unpaid staff that does not know about everything (Jeff Davis GCD 2015, pers. com.).

[100] As described by Brock and Sanger (2003), the effort by the Southern Bexar County to join the Evergreen GCD were fuelled by the concern from residents of San Antonio Water System’s plans to implement an aquifer storage and recovery project on 3,200 acres owned by the utility in the county. The project proposed was to withdraw 14,000 acre-feet of groundwater per year from the underlying aquifer. Under the Evergreen GCD rules, the utility would have been limited to abstract 6,400 acre-feet per year.

Figure 40. Boundaries mismatch between regional water planning areas and groundwater management areas



Source: Sunset Advisory Commission 2011c.

The Sunset Advisory Commission's[101] review of the Texas Water Development Board (TWDB) issued in 2011 reflected on some of the problems facing the TWDB such as the "evolving processes associated with groundwater" and how they affect the "Board's ability to effectively conduct statewide water planning and ultimately affect the management if this vital resource" (Sunset Advisory Commission 2011c: 1). The Commission referred to a controversy regarding the joint planning process through which GCDs join together in regional planning groups and make decisions about the future conditions of the aquifers they manage. This can cause, according to the Commission, problems and might affect the mandate of the TWDB to effectively conduct state-wide planning as the regional planning groups "have no formal input in the amount of groundwater supplies available for meeting future water demands" (Sunset Advisory Commission 2011c: 3). Because GMAs only include representatives of GCDs, the decisions made on groundwater availability "are not fully vetted to determine impacts on water planning strategies and on the State's ability to meet future water needs" (ibid). Additionally, it is the opinion of the Commission that "the Board's process for questioning the reasonableness of a desired future condition decision does not provide for a complete administrative process that ensures the basic elements of due process for those affected by these decisions and ultimately risks making the entire exercise meaningless" (Sunset Advisory Commission 2011c: 1).

Moreover, as the Sunset Advisory Commission (2011c: 24) continues, "Having districts in the GMA make decisions about groundwater availability for water planning ultimately substitutes the districts' narrow interests in groundwater resources for the broad perspective of all water needs and uses, that is the hallmark of the regional – and state – water planning process facilitated by the Board."

[101] The Sunset Advisory Commission is a 12-member legislative commission with the mandate to identify and 'eliminate' waste, duplication, and inefficiency in more than 130 Texas State agencies every 12 years. It is made up of 5 senators, 5 members of the House of Representatives and two public members (appointed by the Governor and by the Speaker of the House). It was set up in 1977 and since then 79 agencies have been abolished (https://www.sunset.texas.gov, Accessed 27th February 2015).

Additionally, the fragmentation of the petition process for questioning DFCs between the TWDB and the TCEQ also represents a problem. There are no standard administrative components to question those desired future conditions so that the submission process can be considered fair, ensuring clear resolution and due process for applicants. The joint planning process to establish the DFCs is independent from the regional water planning process (Sunset Advisory Commission 2011c). They have differences in purpose and scope as regional water planning groups plan to meet all future water needs (including surface and groundwater) whereas GMAs plan only for future aquifer conditions through groundwater regulation in GCDs (ibid.). There is therefore a risk of overlapping jurisdictions and lack of coordination between entities and plans.

The lack of participation of the Regional Water Planning Groups in the DFC set-up process could potentially, according to the Sunset Advisory Commission, undermine the state and regional water planning process as the scope of the regional planning groups is limited. This is because the DFCs "could disallow consideration and implementation of water planning projects to meet future growth in water demand because the available groundwater that results may not be sufficient for the project" (Sunset Advisory Commission 2011c: 25). These recommendations and findings by the Sunset Advisory Commission were reflected in Senate Bill 660, which added a representative of each groundwater management area overlapping with a regional water planning group as a voting member. This Bill also tried to take action regarding the alignment of DFCs and regional plans. It also ruled "representatives of each groundwater conservation district located wholly or partially in each groundwater management area to convene at least annually to conduct joint planning and to review proposals to adopt or amend existing DFCs every five years" (Sunset Advisory Commission 2011c: 42h). Proposed DFCs will also require two thirds of all district members in a management area before they are submitted to each individual GCD for consideration.

8 Conclusions

Texas groundwater regulatory evolution has followed several decades of burgeoning population growth and increasing urban demand, droughts, groundwater over-abstraction, restrictions and limitations on abstractions and water transfers between from rural areas to urban agglomerations (Kaiser 2006). Within this context, the study of groundwater legislation and management in Texas shows the complex relationship between the state and groundwater users, as public legislators attempt to balance natural resource legislation and protection with the respect of private property and the depletion of groundwater resources (Teel 2011).

The political and social structure and the different layers of government in Texas create a complex system of governance on which groundwater management and regulation depend. Texas can be considered an example of multi-level and polycentric governance, where market, state, and communities, all together, interact to regulate and manage groundwater (Somma 1997). Groundwater regulation and management have had to reconcile user abstraction rights at the local level, arising from a long standing tradition of devolved county governance, with increasing checks and balances put in place by the legislature and different state agencies, in order to manage and protect groundwater resources. This generates an intrinsic contradiction and continuous tension between the state and policy-makers, aiming to retain command-and-control powers and their support base, and local authorities and users, enabled and with devolved powers and individual private rights. The multilayered system of groundwater governance found in Texas emerges as a result of this push/pull relation between central governments and the need to respect local communities' rule. As an example, following Teel

(2011), the approval of the 2002 Texas Water Plan increased at the same time the power of regional planning guidelines and the influence of local GCDs. This increase in power for the local districts was granted as a trade-off that would sustain and allow the implementation of the 2002 Texas Water Plan.

According to Porter (2014: 18), "[t]he story of water in the West, and Texas in particular, is one fraught with confusing and conflicting laws and court rulings, a general lack of direction toward a common goal for everyone's benefit, short-sighted legal experimentation that resulted in dual systems of law in many states and territories, and a disjointed approach to water conservation." Laws seeking resource management have been passed, establishing successive layers of regulation and creating a complex patchwork of legal texts and rules. It is hard however to see Texas as a case of proactive regulation but more like a reactive exercise to the historical concessions and power of local rule. The system is geared towards appeasing users with the bottom line of the inalienable private property of groundwater. Regulation has also been reactive to drought episodes in the 20th century. As quoted by Drummond et al. (2004), "[t]he story of water law in Texas is also the story of its droughts".[102] Documented droughts in 1910 and 1917 "spurred the passage of Article XI, Section 59 of the Texas Constitution, which is commonly referred to as the 'Conservation Amendment', imposing the duty to preserve Texas's natural resources on the Texas legislature" (Drummond et al. 2004: 42) and after the sustained Dust Bowl drought in 1949, GCDs were created.

The creation of GCDs in Texas over the years has resulted in a complex system of local structures to manage groundwater, showing a high degree of adaptation of both its rules and also of its scope towards water conservation. However, as Emels and Roberts (1995) pointed out, some regulation by GCDs (e.g. well spacing) was aimed at prohibiting excessive local depletion but was not intended to constrain production. For these authors, well spacing requirements did not impede the development of water. The enforcement capacities of the districts, backed by the power of the courts, are rarely used as this regulation via the judiciary is not preferred by the district and solutions are usually worked out with landowners (ibid.). Thus, it would seem that the objective of conservation districts such as the High Plains Underground Water Conservation District is "to maintain the accumulative potential of individual property by influencing the productive allocation of resources to meet the changing patterns of efficient capital accumulation" (Marsden 1986 in Emels and Roberts 1995: 679).

The decentralized nature of GCDs makes them vulnerable to political co-optation, conflicts, and electoral scrutiny by local interests favoring unsustainable pumping and economic gains (Porter 2014; Welles 2013). Rules are applied lightly within a system that remains 'user-friendly' and with fearful suspicions of future state meddling and curtailment of private rights. GCDs have little regulatory authority and lack enforcement capacities. They have limited technical ability and lack resources, relying instead on persuasion and the ability of its staff to alter social expectations about groundwater use (Somma 1997). Most GCDs have funding challenges due to their small financial base as they have "statutorily restricted water use fee rates and low ad valorem taxation rates" resulting in small budgets, limited office space and opening hours, and lack of staff (Porter 2014: 81). As Porter (ibid.) puts it, "[m]any times voters express their keen desire to establish a GCD but are not willing to vote any amount of additional taxes for adequately funding it." Following Welles (2013: 493), "although legislators and managers have recognized the negative effects of these problems on the state's ability to conduct effective and

[102] Quoted by Drummond et al. (2004: 1), from the re-adjudication of the water rights of the Upper Guadalupe Segment of the Guadalupe River Basin, 642 S.W. 2d 438,441 (Tex. 1982).

coordinate water supply policy, a decentralized system is likely the only politically tenable groundwater management strategy in Texas".

Against this backdrop, the sustainability and management of groundwater in Texas is heading towards an uncertain future. Local managers and users should and have an interest in preserving such resource. As they say so themselves, "this is considered a desert, we people know how to conserve water" (Jeff Davis GCD 2015, pers. com.), or "I want the young generation to have it for the future" (Middle Pecos GCD 2015, pers. com.). However they also do not want to cut back on anybody's right to pump groundwater (Jeff Davis GCD 2015, pers. com.), or can even "disagree with management permits" altogether (Middle Pecos GCD 2015, pers. com.). Somma (1997) called GCDs in Texas "an unintended experiment in commons resource management" referring to the autonomous nature in which they are allowed to set abstraction rules and enforce resource conservation measures. At the same time, the established 'Desired Future Conditions' for 2060 modeled by some of the GCDs' groundwater management plans can contemplate reductions of 40 to 50 percent of groundwater levels found in aquifers. However, the 'gerrymandering' of GCDs, county lines, and aquifer boundaries causes hydrological disconnect and political manipulation. As a result, it would seem that groundwater management in some GCDS in Texas is, after all, about preserving the economic activities based on groundwater abstraction while leaving enough margin for future expansion. This arrangement would preserve the lion's share for irrigation and delay politically risky decisions rather than seeking the sustainable management of the resource and preventing further depletion.

Groundwater governance in Texas is enabled through the constant political dialogue between state rule and local communities, surrounded by the lobby, legal work, and interests of users and decision-makers. As Kaiser (2006: 485) wrote, Texas made "Faustian choices in allocating, managing, and protecting its groundwater resources. In adopting the laissez-faire capture rule, the Texas Supreme Court sought to minimize political and legal conflicts over groundwater ownership and management, but it left Texas landowners without a remedy for well-interference disputes, and it left Texas aquifers subject to harmful over-pumping and mining." This laissez-faire attitude has, for a while, "minimized political conflicts over governmental management and control of groundwater pumping" but has "left Texas aquifers subject to uncontrolled and harmful pumping" (Kaiser and Skiller 2001: 251).

The use of the rule of capture and respect of private property does not imply a total lack of state involvement and governance exists through different layers, amidst a "slow transition towards larger-scale management" (Dupnik 2012: vi). New rules and structures have been put in place in order to consolidate groundwater management practices across the state while maintaining GCDs as the 'preferred' method of groundwater management. As Teel (2011: 76) reflects, the history of groundwater conservation districts in Texas is the story of "the public regulation of a private resource". The GMAs and regional water planning groups are attempts to organize and integrate management at a regional level amongst the large diversity of uses and users, climate patterns, and GCDs. However, the piecemeal regulation and management of the resource complicates and sometimes limits the capacity of public institutions to clearly and effectively protect the resource while balancing out users' needs.

As a result of these intrinsic tensions, the sustainability and future of Texas groundwater resources are at a crossroads. Room for maneuver is however shrinking as the conditions for continuous groundwater abstraction being laid out are progressively enforced, enabled by the current system of groundwater governance. The quote from *The Leopard* by Giuseppe Tomasi di

Lampedusa at the beginning of this report echoes back. No matter the changes in groundwater governance in Texas, the system of property rights and small-scale management is maintained. The preference for GCDs has now become a political necessity and a compromise in the never-ending quest for effective groundwater management within such a constrained system.

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Part 2. Groundwater governance in Nebraska

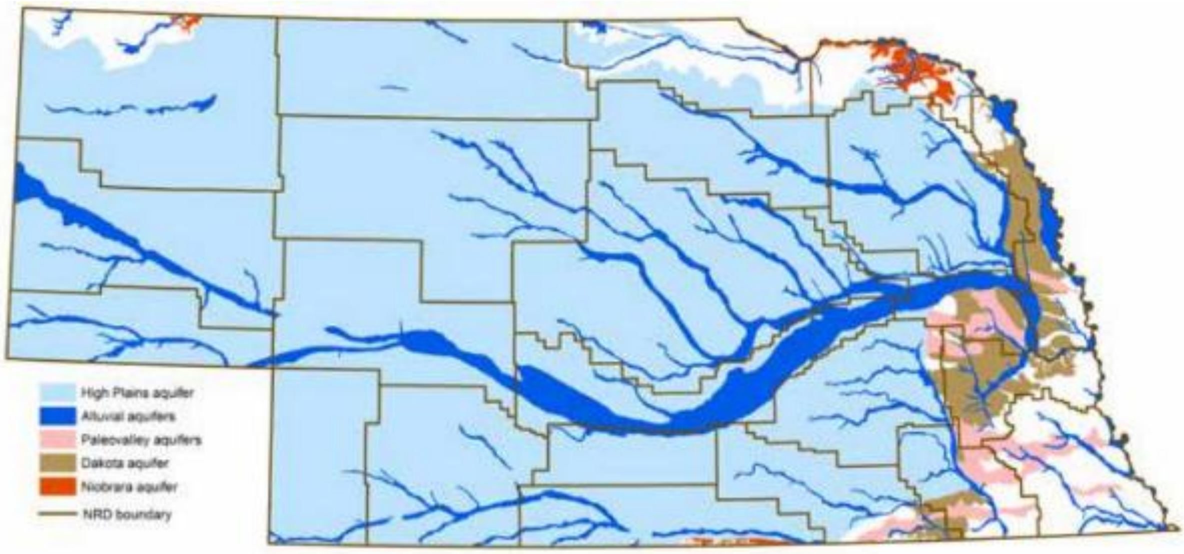
1 Groundwater management and regulation in Nebraska

1.1 Groundwater resources in Nebraska

Nebraska overlies part of six river basins: the Niobrara, Upper Platte, Lower Platte, Blues, Republican, and Missouri whilst the High Plains aquifer (also known as the Ogallala aquifer) underlies most of Nebraska. Groundwater depths range between 0 to 300 feet (0 to 92 metres), with some instances of very high connectivity to surface water courses. The volume of groundwater stored in the Ogallala formation is distributed among several states, from about 40 billion cubic meter (Bm3) in New Mexico to about 2,400 Bm3 in Nebraska (McGuire et al. 2003; Scanlon et al. 2012). As Kepfield (1993: 241) put it, "the lion's share of the Ogallala Aquifer, roughly one-fourth of its 220,000 square miles, lies under Nebraska", with 65 percent of the aquifer's volume and two thirds of its land mass underlain by it (Peck 2007; Sugg et al. 2016) (Figure 41). Thick layers of sediment and sand formations constitute large reservoirs of groundwater in Nebraska. Saturated thickness of sands and sandstone can exceed 300 metres in several places (Fricke and Pederson 1980).

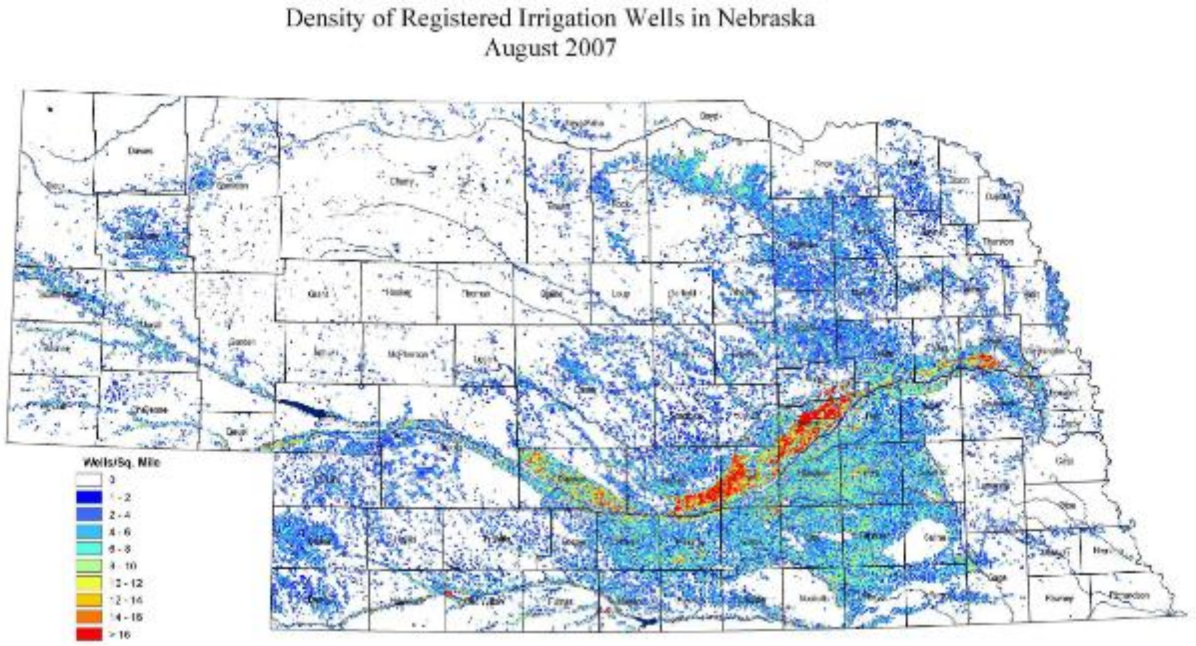
Groundwater withdrawal for irrigation represents 94 percent of total withdrawals and 85 percent of all water used in irrigation is from groundwater sources (Kelly 2010). Nebraska has the largest extent of land under irrigation in all of the United States and is also the third largest groundwater user (behind California and Texas) (ibid.). The number of centre-pivots in use, rose from 2,700 (for 151,000 hectares) in 1972 to 26,208 irrigating 1,360,000 hectares in 1986 (Bleed 2012). In 2010 there were over 107,000 registered wells in Nebraska (an increase of 20 percent over the 2000-2010 decade) (Figure 42 and Figure 43) (Kelly 2010). The number of wells however has dropped since then, with 96,131 registered and active irrigation wells supplying water to 8.3 million acres of land (USDA NASS 2015). The state ranks third in corn production and fourth in total livestock receipts in the United States (Bleed and Hoffman Babbitt 2015).

Figure 41. Main aquifers in Nebraska



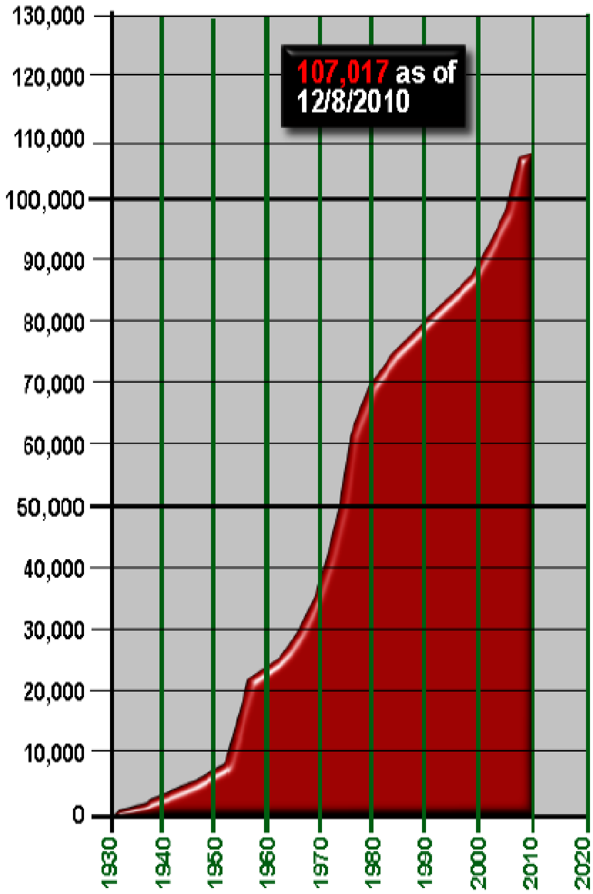
Source: Bleed and Hoffman Babbitt 2015.

Figure 42. Density of irrigation wells by county (2007)



Source: Bleed 2012.

Figure 43. Cumulative total number of wells registered in Nebraska (1910-2010)



Source: Nebraska Department of Natural Resources in Johnson et al. 2011.

1.2 Groundwater depletion in Nebraska

Even if Nebraska's groundwater reserves are very large and even though only 1 percent of groundwater stored has been depleted in Nebraska, there are localized groundwater depletion problems, reducing well discharge as well as groundwater baseflow to some of the rivers in the state in areas with shallower water tables (Scanlon et al. 2012). Throughout southern parts of the state, groundwater level decline from 5 to 40 feet are considered common (between pre-development levels and 2008) (Kelly 2010). In other areas however, groundwater levels show increasing trends (Scanlon et al. 2012; Young et al. 2013). Generally, the areas of significant groundwater decline correspond to those areas with high well density for irrigation and deep aquifers with no connection to surface water. As Figure 45 indicates, the largest areas with groundwater declines are found in the southwestern and in the eastern part of Nebraska. The areas with groundwater-level rises usually coincide with areas of surface water irrigation (caused by seepage losses and deep percolation around irrigation-distribution systems and water reservoirs, e.g. Lake McConaughy) (Young et al. 2013).

Prior to 1981 groundwater levels had been declining driven by the proliferation of irrigation (drops of up to 9 to 12 metres) had been recorded over the years. Groundwater pumping also reached new records in the mid-1970s when drought revisited the High plains in Nebraska (Kepfield 1993). Average groundwater levels in 1976 had been lower in 91 out of 93 counties in the state than the previous year (with declines greater than 0.3 metres in 41 counties) (Fricke and Pederson 1980). After 1981 however, improvements in irrigation efficiency, extended above-average precipitation levels, and potentially the lagged impact of recharge from previous years stabilized aquifer levels in eastern parts of the state (Bleed and Hoffman Babbitt 2015). In the west, however, groundwater abstraction continued to deplete the resource, with decreases of up to 18 meters in 50 years (an average of 0.3 metres per year) (ibid.).

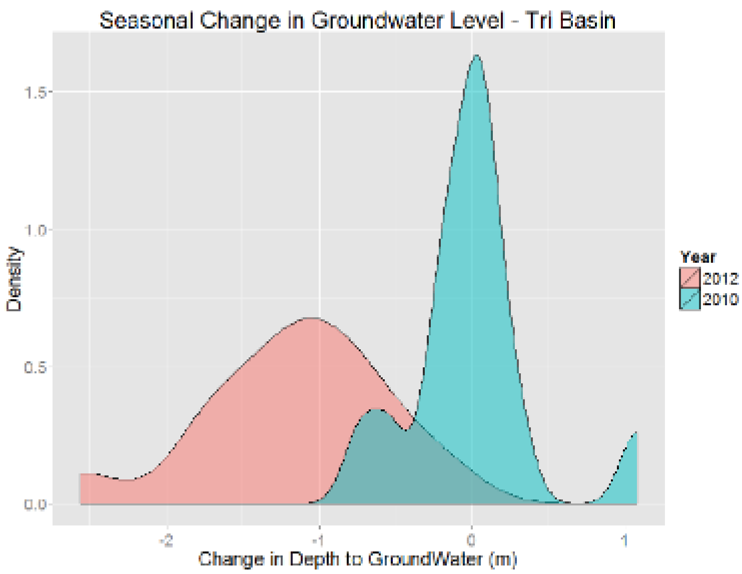
Despite the increasing importance of groundwater withdrawals, according to Siebert et al. (2010) there is large uncertainty regarding volumes and the spatial distribution of these withdrawals. Estimates for groundwater withdrawal for irrigation are compiled every 5 years and based on state-wide average estimates and past studies estimated long-term averages, using meteorological variables, rarely validated against actual volumes (Boone 2015). Estimates also differ inter-annually and depending on the type of user who does them. The Upper Big Blue NRD reported for instance that, on average, water use in Nebraska for crop irrigation dropped almost 28 percent over a year (2013-2014), averaging 7.3 inches in 2014 compared to 10.1 inches per acre in 2013. The decline is attributed, according to the President of the Nebraska Association of Resources Districts (NARD) to increased precipitation levels as well as the state's groundwater management system, which tends to mitigate water use increases "during dry periods and significantly decrease water usage in years with moderate increases in precipitation, resulting in a sustainable balance over the long term" (Blueprint 2015).

Newspaper reports however portray a different picture, as such decrease in groundwater use followed 'unprecedented' groundwater decline levels in 2013, as farmers increased abstraction in response to record low precipitation levels in 2012 (following what was considered one of Nebraska's historic droughts) (Omaha-World Herald 2014a; Swanson 2012). Groundwater levels declined in 90 of the state's 93 counties between spring 2012 and spring 2013 and aquifer levels dropped 2.5 feet on average. This record drought forced farmers to start irrigating a month or two earlier than normal (Omaha-World Herald 2014a). During this period, the Upper Niobrara White NRD (North-west Nebraska), for example, reported groundwater level declines of up to

8.39 feet. No new irrigation wells are allowed in the NRD and restrictions are in place for increases in irrigated areas in the majority of the land area of the NRD.

There is also important interaction between the availability of surface water, precipitation, recharge and groundwater in Nebraska. For Kelly, "the increasing use of groundwater, especially in areas where the groundwater has historically provided substantial input to stream flow, is one of the most prominent challenges facing state decision-makers" (Kelly 2010: 10).[103] These phenomena have been investigated by Boone (2015) and shown in Figure 44. According to her research, during wet years mean groundwater level change was approximately zero and during dry years mean change was approximately 1 metres decrease (between 2005 and 2013). Irrigation can vary up to three times between wet and dry years, with soil compositions potentially explaining variations in irrigation amounts depending on the areas (ibid.). According to John Turnbull, Manager of the Upper Big Blue NRD, "People look at the maps of the state that show the dots of irrigation wells, and they're dense in this area. And some people draw the conclusion because of all those wells there has to be a problem. Not necessarily. What we found at the Natural Resource District in looking at this problem for a number of years is […] the groundwater level is really tied to the weather cycles. […] So, we plotted this from 1961 to 2003, and we laid that rainfall change chart over the top of the groundwater decline chart and they match […]. So we're convinced that rainfall produces a lot of groundwater recharge for this aquifer. We're in windblown Loess soils of 70 to 100 feet thick – that's the yellow clays – and water moves through that fairly rapidly. Now it doesn't happen in one year, but it does move vertically through that. What happens, in the wet year, we have the recharge going on plus people aren't pumping as much. In a dry year, the water's not moving as much, but there's more pumping. So, that's what it's tied into." [104]

Figure 44. Seasonal changes in groundwater levels for the Tri-Basin NRD



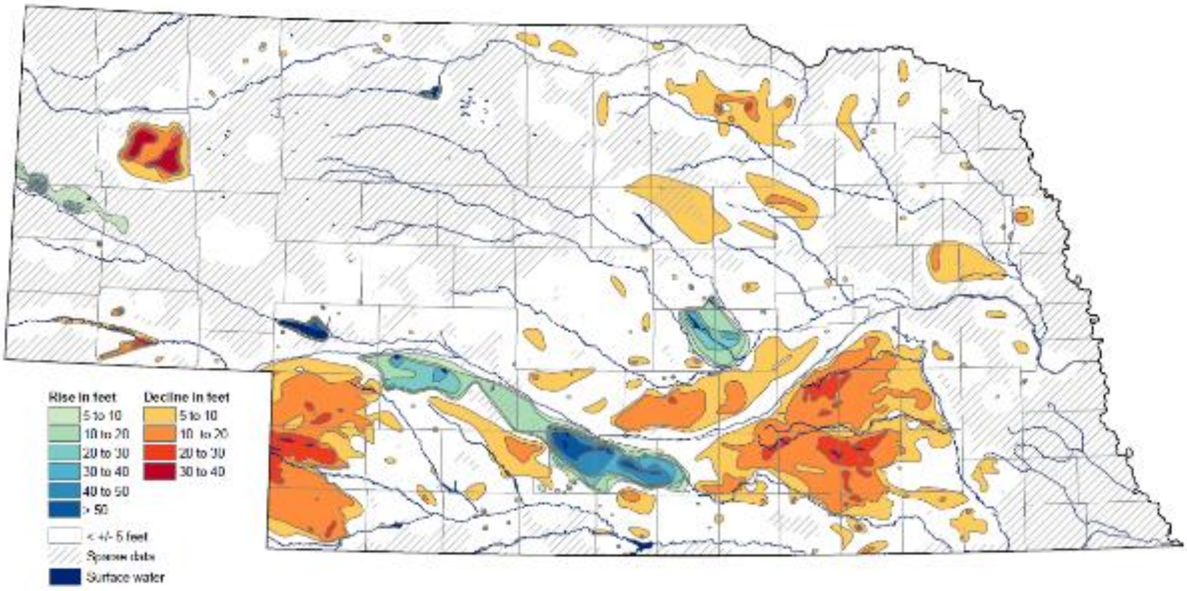
Source: Boone 2015.

[103] These issues arose within the context of Nebraska's commitments to river flows on the Republican River with its neighbours downstream (Colorado, Kansas). The issues regarding the interaction between groundwater and surface water will be further expanded in later sections.

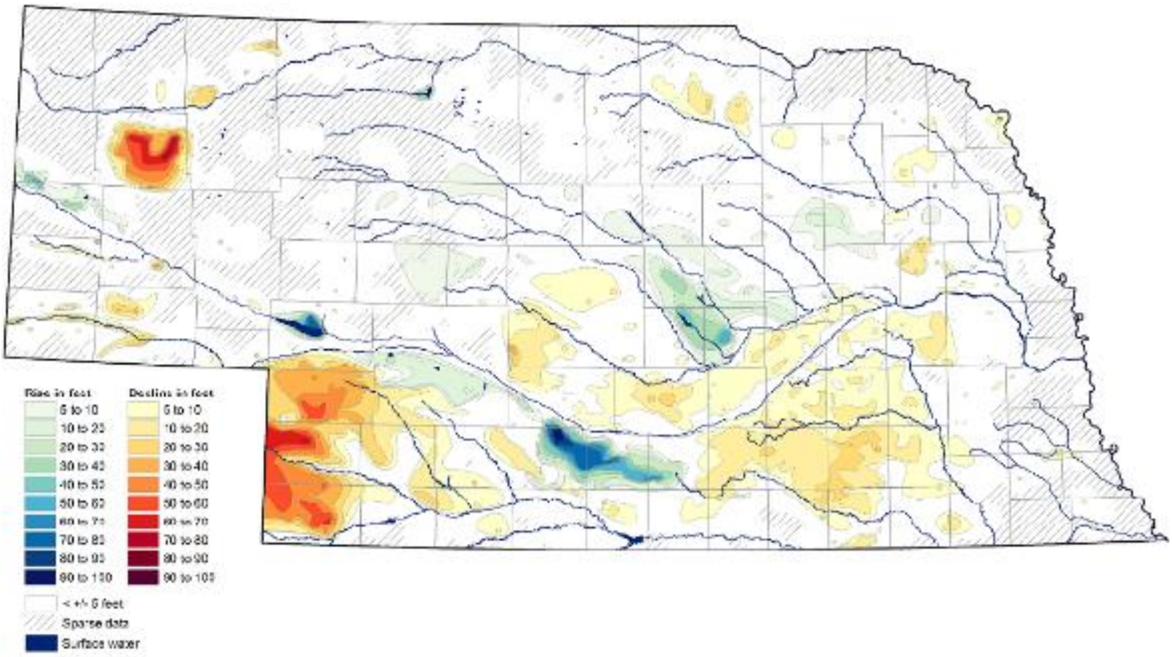
[104] Ganzel, B. 2006 "Nebraska's unique Natural Resource Districts", Interview with John Turnbull, http://www.livinghistoryfarm.org/farminginthe50s/movies/turnbull_water_11.html, Accessed 18th January 2016.

Figure 45. Groundwater level changes in Nebraska

a) Pre-development to 1981

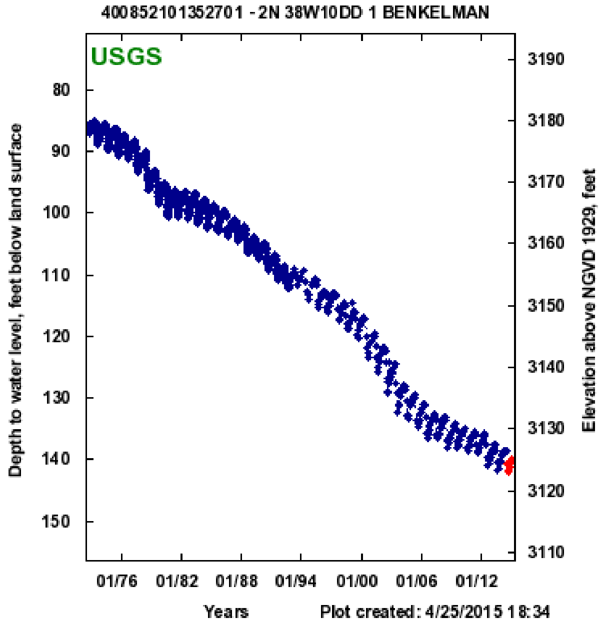


b) Pre-development to spring 2013

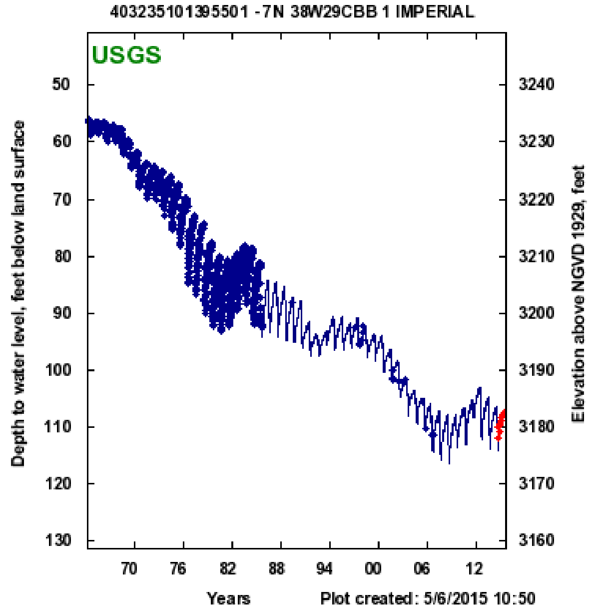


Source: Young et al. 2013.

Figure 46. Groundwater levels in the Ogallala Aquifer formation, South-west Nebraska



South-west Nebraska, Benkelman (URNRD)
Well depth: 180 feet.



South-west Nebraska, Imperial (URNRD)
Well depth: 230 feet

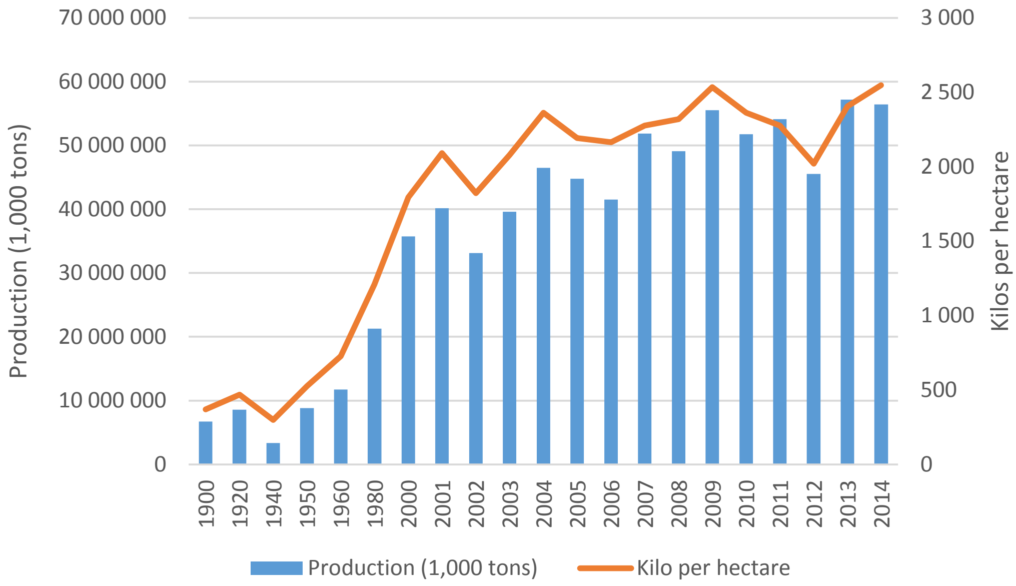
Source: USGS, http://groundwaterwatch.usgs.gov/netmapT4L1.asp?ncd=NCG (Accessed 30th April 2015).

1.3 Agriculture in Nebraska

Nebraska ranks first in the USA in total irrigated crop area and corn production has continued to rise over the years, lately driven by the ethanol/bio-fuel craze (Zellmer 2008) which poured targeted subsidies to encourage soy-based biodiesel, followed in 2005 by stronger subsidies for the production of grain crops for ethanol (Jones 2012). This is a result of the desire to minimize the reliance of the United States on unstable oil supplies from the Middle East, as well as to minimize greenhouse gas emissions from fossil fuels (Zellmer 2008). This surge was also driven by the 2007 Energy Bill, requiring a fivefold increase in the use of biofuels (with the declared goal to reach 133 Mm3 of produced biofuel per year in 2017), boosting the demand for corn and therefore prices as well as the package of subsidies included in the 2007 Farm Bill, continuing long-standing financial aid to farmers growing corn (ibid.). In order to achieve these targets, land use restrictions were also relaxed. The increase in agricultural yields is due both to the change towards more high-yielding crops (e.g. corn) and the increased use of fertilizers and higher yielding crop varieties (Figure 47) (ibid.).

Nebraska ranked second in 2012 in ethanol production capacity in the US and over 40 percent of the state's 2011 corn harvest was used for ethanol production (Nebraska Department of Agriculture 2013). As Figure 47 shows, Nebraska's corn production increased from 3.3 billion tons in 1940 to over 56 billion tons in 2014. Farmers producing crops for biofuel in Nebraska are also protected by the Initiative 300 legislation, specifically designed to "prevent the spread of major out-of-state agro-industrial corporations into the State" (Jones 2012: 51). This initiative was passed in 1982 with the aim to protect the land from environmental degradation caused by corporate farming (Jones 2012).

Figure 47. Corn production and yields in Nebraska



Source: Based on data from Nebraska Corn Board (except for 2013 and 2014: USDA).

1.4 Groundwater legislation and regulatory tools in Nebraska

According to Aiken (1987: 9), Nebraska's state water policies have followed federal policies, historically seeking to facilitate private and public irrigation development and establishing communities and agricultural development in "what was considered to be a vast wasteland."[105] This trend however changed during the 1970s when the environmental movement of the decade and federal budget constraints in the 1980s dealt significant blows to the traditional approach to irrigation and land reclamation in the West (Aiken 1987). What also transpires from Aiken (1980) and Kepfield's (1993) research on groundwater policy in Nebraska is that drought has been a major driver of irrigation innovation, groundwater abstraction and groundwater legislation in the state. Legislation however has dragged behind by about one generation (Kepfield 1993).

1.4.1 Drought, legislation, and the development of groundwater irrigation in Nebraska

The 1895 Water code in Nebraska created an administrative agency to grant and administer appropriative rights for surface water irrigation: the Board of Irrigation, which was authorized to deny permits if a stream was over-appropriated or if the permit to be granted was not of public interest (Aiken 1987). Irrigation district legislation was also enacted in 1895 with the Irrigation district Act, allowing a majority of water users to create irrigation districts by petition (governed by a board, with water charges or property taxes paying for district organization, O&M, and the construction of canals and reservoirs) (ibid.). The Reclamation Act of 1902 added further federal funds to the establishment of surface water irrigation in the West by establishing financing mechanisms and federal subsidies for irrigation projects (funded through receipts from the sale of reclaimed land in sixteen states) (ibid.).

[105] This can be exemplified by the replacement of the common law precept of riparian rights for surface water (each riparian user has coequal rights to make a reasonable use of water) with the statutory water allocation doctrine of prior appropriation (allowing water to be used on non-riparian land, and new users taking subject of existing rights) (Aiken 1987).

A drought in the 1910s and rising commodity prices stimulated irrigation during that decade but the cost of pumping devices remained too high for farmers (with the lack of credit system to aid in their purchase) (Kepfield 1993). The drought that brought the Dust Bowl and the depression in the 1930s led to an increase in activities of the land reclamation program by the federal government. The drought also fostered the surge of groundwater development in Nebraska, as farmers realized that irrigation was a secure form of crop insurance (in 1935 over 1,000 wells were drilled), coupled with increasingly cost-effective centrifugal pumps after the 1920s (Aiken 1987; Kepfield 1993). By 1928, the impact of groundwater irrigation in parts of the state was already enough "to dispel the idea that the resource was unlimited" (Jones 2012: 16). The state sought to control this phenomenon, further fuelled by the development of electric-powered in-line shaft pumps (Jones 2012).

The 'sharing rule' in Nebraska which informed the 'correlative rights' doctrine ruling groundwater access in the state was first codified in 1933 during the Dust Bowl years (Mossman 1996). The Nebraska Supreme Court decision in *Olson vs. City of Wahoo* ruled that groundwater was not the sole property of the landowner and that it had to be shared by competing users during periods of water scarcity (ibid.). The Nebraska Supreme Court added its twist to the rule of appropriation and established that all users are entitled to a reasonable proportion of water, becoming the modified doctrine of correlative rights (ibid.).[106] During this decade also, the national Soil Conservation Service was created in 1937, enabling local soil conservation districts to help farmers combat the soil erosion and dust storms of the 1930s. Under this law, soil and water districts were created, with broad responsibilities and enforcing land use regulation (rarely implemented though) (Bleed and Hoffman Babbitt 2015).

Around that time, rural electrification programs, as a consequence of the New Deal after the Dust Bowl, provided electricity to power more efficient pumps, easier to maintain than gasoline pumps (Kepfield 1993). Also during this period, a River Compact for the Republican River was signed in 1942 between Nebraska, Kansas, and Colorado allowing the states to share surface water and retain control of water usage and secure federal flood control and reclamation projects (without mentioning groundwater).[107] The first major attempt at groundwater regulation came in 1940, when the Regulation of the Use of Groundwater in Nebraska was prepared for the Nebraska Legislative Council and a Legislative Bill was prepared but then withdrawn (Aiken 1980). The Bill would have established a state-wide permit system for groundwater, with quantities allocated according to the aquifers' sustainable yields and potential development by other landowners (ibid.).

1.4.2 Groundwater controls and the Natural Resources District: a local agency to manage and regulate groundwater in Nebraska

Initial attempts to regulate groundwater initiated in Nebraska in the 1940s were opposed by reluctant legislators, merely reflecting the wishes of the constituents, as they did not believe in the 1950s that a crisis over groundwater depletion was forthcoming (Kepfield 1993). In the 1950s however it was already evident that groundwater resources were no longer inexhaustible, with all-time low levels in the mid-1950s throughout the 1960s (ibid.).

A subsequent drought in the 1950s – called 'The Little Dust Bowl', combined with the appearance of sprinkler irrigation technology, brought a further expansion of groundwater-fed

[106] Later, in 1975, the Groundwater Management Act embodied this principle (Aiken 1987; Peterson et al. 1993).

[107] See Section 1.5 for more detail.

irrigation (e.g. in 1959 in Nebraska, the area irrigated with groundwater became larger than the area irrigated with surface water) (Aiken 1987; Kepfield 1993). This led to the realization that excessive development of this resource could lead to its depletion. In 1957 the state passed the first revision of its legal and technical management measures for wells, fixing a minimum distance between wells of 200 metres, and registration for irrigation wells (Aiken 1980; Jones 2012). Wells in Nebraska had to be registered (20 days maximum after the completion of the well). The driller is the responsible person for forwarding the registration form along with the driller's certificate to the Department of Natural Resources (previously Department of Water Resources) (Axthelm 1988). As a result, in 1959 Nebraska passed the Groundwater Conservation Act, authorizing the creation of conservation districts at the local level, authorized to establish corrective measures to "ensure the proper conservation of groundwater" (Aiken 1980: 950).[108]

At that time however, the incentives for private well owners "to impose controls upon themselves" and join and NRD were already questioned by Hansberger (1963: 755-756). Most irrigation investments (e.g. wells) are private and "farm owners and operators therefore are reluctant to recognize that control is a matter of state wide concern rather than an entirely local matter." Nevertheless, following the 1959 Groundwater Conservation Act, Groundwater Conservation Districts were created in the 1960s and 1970s in 5 counties in the Blue River Basin forming the Blue River Association of Groundwater Conservation Districts, coordinating enforcement of groundwater irrigation runoff,[109] control regulations and promoting efficient use of groundwater through irrigation scheduling programmes (Aiken 1980).

The consolidation of a large number of resource districts and small government units which had been created loosely during the previous decades was one of the main arguments for legislative changes later on (Fischer et al. 1970). Amounting to a total of over 500 at the end of the 1960s (including 150 single-purpose districts – mostly soil and water conservation districts), their large number had already been recognized as a pressing issue in 1939 (ibid.). In 1964, the District Outlook Committee of the National Association of Soil and Water Conservation Districts, viewing the multiplicity of tasks and services offered by these associations, recognised "that a strong local unit of government was needed – one that could more comprehensively tackle resource problems. […]. Although they analysed the situation adequately, their recommendations were less than adequate and quite ambiguous. They concluded that soil and water conservation districts should be strengthened with no guidance as to how or to what extent, and they offered no solution to the then present disarray of special purpose districts and their coordination problems" (Jenkins 1975: 1-2).

It was only in 1966 that much of the work was laid for the eventual reorganisation of water management in Nebraska, with recommendations for administrative and management

[108] Groundwater Conservation Districts would be created by a petition signed by no less than 5 resident owners or 51 percent of the resident owners of land in each of the precincts lying in the proposed district would be certified by the election commissioner or county clerk to the County Board. After a public hearing, the Country Board can "change the boundaries of the district subject to court review. Once the boundaries are established, an election is held in each county containing a part of the proposed district; and the district may be created if fifty-five percent of those resident landowners vote in favour of organization" (Hansberger 1963: 754).

[109] These tasks would control improper irrigation run-off in order to prevent flooding and also extend 'groundwater reservoir life'. Standards and criteria would be issued as well as specific procedures to be undertaken in order to abate such run-off. These included the construction of special collection and retention systems, the reuse of runoff through pumps back into the fields or for other beneficial uses, the blockage of rows or fields to contain irrigation water, the agreement between two or more users for the utilization of any runoff (South Platte NRD, Groundwater Runoff program, Rules and Regulations, January 1978, http://www.spnrd.org/PDFs/Rules_Regs_Programs/Ground_Water_Runoff_Program.pdf, accessed 28th January 2016).

organisation changes, and new legislation made to the Legislative County Study Committee on Water and to the Board of Directors of the Nebraska Association of Soil and Water Conservation Districts by the National Association of Soil and Water Conservation Districts (Jenkins 1975). Out of these conversations, Resolution 18 came out of the Annual Conference of the Nebraska Association of Soil and Water Districts, calling for legislation to reorganise the districts along hydrologic units rather than county lines "and that such newly formed districts be of sufficient size to facilitate economy of operation and effectiveness of purpose. It also called for districts to be granted the necessary tools to carry out and sponsor comprehensive programs of land and water development, and that such districts be governed by locally elected representatives, both rural and urban, to assure local control" (Jenkins 1975: 2) (Figure 48).

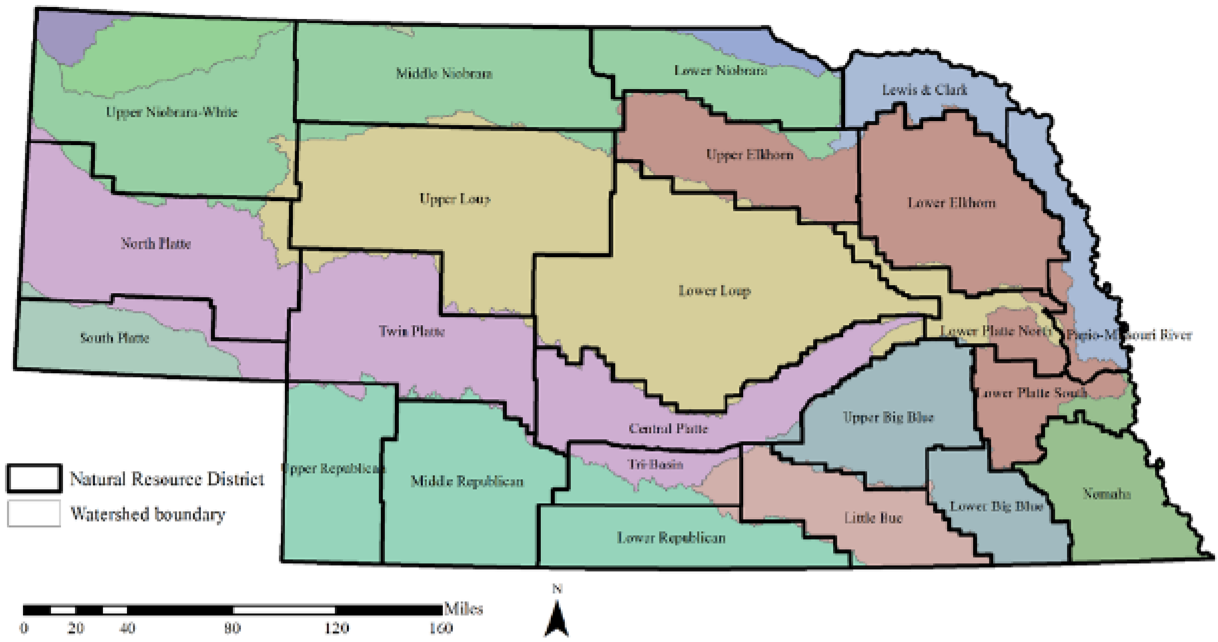
Legislative Bill 1357 was adopted in September 1969, calling for Natural Resource Districts to commence operation on January 1st, 1972. This legislative initiative defeated opposition from several districts in the Southeast and the watershed boards. Opposing districts and watershed boards filed a lawsuit against the new law, claiming amongst other legal points that it violated several principles of Nebraska's Constitution, such as private property, without due process of law "and the taking of private property for works of public improvement without just compensation" (Jenkins 1975: 16).

These districts however, following Aiken (1987), were instrumental in raising public awareness about improved irrigation practices – irrigation scheduling, making a great degree of groundwater regulations more 'acceptable' by users. The newly adopted Natural Resource District system was organized along river boundaries and replaced the single-purpose districts based on county lines with responsibilities assigned according to political boundaries) (Aiken 1987). The 1969 Law of NRDs however did not supply any methods for refereeing groundwater rights and allocating groundwater in areas with scarcity (Kepfield 1993).

NRDs were created as "multipurpose resource districts" and were given a wide range of management responsibilities (e.g. soil and water conservation, flood and soil erosion control, drainage, rural water supply, forestry, solid waste disposal, fish and wildlife protection) (Bleed and Hoffman Babbit 2015: 35). NRDs were established as the central figure for groundwater management, based on river basin boundaries, enabling them to approach water management resources at a watershed level. A board governs the NRD, elected amongst the citizens living in the district (not only water users) and the size can range from 5 to 21 members depending on the population and land area and they would be elected for a 4-year term (Hoffman and Zellmer 2013). In the end a total of 24 NRDs were created.[110]

[110] Nowadays there are only 23 as in 1989 the Papio NRD and the Missouri River NRD merged into one NRD, the Papio-Missouri River NRD.

Figure 48. NRD boundaries and river basins in Nebraska



Source: Sugg et al. 2016.

1.4.3 Subsequent groundwater legislation during the 1970s

By the 1970s, state and federal policy changes made it more difficult to develop large infrastructure projects and proposed policy reforms resulted in a significant reduction of federal assistance for public irrigation projects and increasingly stringent environmental protection statutes and laws (Aiken 1987).[111] Prior to 1975 groundwater in Nebraska was regulated and managed through piecemeal judicial and legislative rules. The legislative tradition respected the 'reasonable use doctrine' which essentially granted nearly unlimited rights to access and pump groundwater to overlying land owners (Stephenson 1996). The threat of groundwater depletion in Nebraska has been historically viewed as a justification for surface water diversion projects (Aiken 1987; Stephenson 1996).

In the 1970s however, following drops in groundwater levels fuelled by the advent of high-capacity abstraction pumps and the agriculture boom during the previous decade, Nebraska's Parliament enacted the Groundwater Management Act in 1975, granting primary responsibility for natural resources management to local Natural Resource Districts (NRDs) (Stephenson 1996). The creation of NRDs also benefited from a strong and 'aggressive' governor, and personal leadership (both at the state and at the local level) "was at the heart of Nebraska's effort" to manage groundwater (Bleed and Hoffman Babbit 2015: 35). Existing Groundwater Conservation Districts had to be dissolved by April 1st, 1982, as groundwater became a function assumed by NRDs (Aiken 1980).

The Groundwater Management Act of 1975 granted the board of NRDs discretionary powers to regulate groundwater use (Stephenson 1996). According to the 1975 law, NRDs can limit total

[111] Such as the Wild and Scenic Rivers Act of 1968 aimed at protecting environmental values of rivers, the National Environmental Policy Act of 1969, the 1972 Amendments of the Federal Water Pollution Control Act, and the Endangered Species Act of 1973 (Aiken 1987).

withdrawals by allocating volumetric limits to specific groundwater users in 'groundwater control areas' (later called 'groundwater management areas'), or by implementing rotational pumping schedules, and groundwater meters in wells. The NRDs can also enact additional rules not mentioned in the Act but deemed necessary to manage the resource. However, one of the deficiencies of the NRD regulation is that groundwater controls remained a local option, and where groundwater is being mined the establishment of such rules cannot be implemented until the mining is imminent or is already happening (Aiken 1980). Additionally, the 1975 Law did not make a distinction between 'use controls' (e.g. limitations on withdrawals) and 'development controls' (e.g. well spacing) and it would seem that because either can be exercised within a designated control area the criteria for the designation of these areas have been interpreted conservatively (ibid.).[112]

The 1975 Groundwater Control Act also supplemented the 1969 Act and covered the integrated management of resources (connecting groundwater to surface water) (Jones 2012). If the initial controls set up in a designated control area are not properly enforced, following the 1975 Law, five percent of well owners or any designated body of a municipality owning wells within the area can petition the Director of the Department of Natural Resources (DNR) alleging that the controls are not being enforced properly, uniformly, equitably, or in good faith (Axthelm 1988). If this is the case, the Director will take over enforcement powers from the NRDs for a year (after that the power will revert back to the NRD) (ibid.).

According to Fricke and Pederson (1980: 548) however, the Groundwater Management Act of 1975 was "vague in its provisions regarding how control areas should be determined, what objectives should be considered in an NRD’s formulation of ground-water controls, and what criteria the DWR should use in approving regulations proposed by an NRD." These authors added that the trigger mechanisms for declaring control areas might arise too late, if the requisite of 'inadequacy of groundwater supply' is the sole reason for establishing a control area, when the crisis has already developed. According to their view, the 1975 Groundwater Management Act was limited in its scope as the grounds of inadequacy of supply did not allow addressing a variety of other issues (groundwater quality, conflicts between surface and groundwater uses) (ibid.). Also, following Peterson et al. (1993: 46), it was only at the NRD’s request that control areas could be declared, so "if the local NRD elects to ignore its depletion problems, the state has no authority to undertake the regulatory process on its own motion. As a result, progress in dealing with groundwater depletion in Nebraska has been limited up to the present."

It would therefore seem that the NRDs have tried to implement laws that would grant them authority and independence to manage groundwater, and the state has granted such role to the NRDs. This is the case for groundwater control areas, which had been considered as state provisions too but only given to NRDs during the legislative debate (Peterson et al. 1993). The introduction of groundwater control areas arose, as Peterson et al. (1993) suggest, out of dissatisfaction from some NRDs whose request for the designation of control areas to deal with well interference had been refused by the state as groundwater supplies were not being depleted. These NRDs concluded as a result that they needed additional authority to regulate groundwater uses (ibid.). Fricke and Pederson (1980) present a more positive and collaborative relationship between the state and NRDs. For them, the role of the DWR is to prevent "hasty or

[112] The 1975 Law states that groundwater controls cannot be established “until ground water supplies clearly will be inadequate in light of current development” (Aiken 1980: 994).

unreasonable action by an NRD and to initiate action when and NRD board fails to act" (Fricke and Pederson 1980: 548).

1.4.4 State pull and groundwater legislation in the 1980s

The centralizing pull at the federal level was mostly felt when President Carter issued his 'water project hit list', a list of 19 to-be-decommissioned projects out of 300 water projects approved by Congress in 1977.[113] The list of projects also included water policy initiatives aiming at imposing cost-sharing requirements on project water users, requiring as well substantive changes in state water laws to qualify for federal funding (Aiken 1987). Governors and state representatives protested, accusing the President of "being ignorant of western water needs" (Aiken 1987: 52). In the end, even if Carter's water policy initiatives were not implemented, the de-authorizations of projects were, and the subsequent Reagan administration included some of these elements (the Water Resources Development Act of 1986 enacted new cost-sharing requirements for infrastructure projects with local or state having to contribute in varying measures according to the type of project) (ibid.).

To break with this, the Governor of Nebraska appointed a 'Water Independence Congress' in 1983 with the aim to develop new water policies and accommodate water needs and environmental concerns (ibid.). The recommendations of the congress resulted in the creation of a Water Management Board to oversee the promotion of water projects in Nebraska, a measure aiming to keep the status quo and continue seeking federal projects to maintain surface water irrigation at the expense of the federal government (Aiken 1987).

Based on the recommendations of the Water Independence Congress, Law LB 1106 was introduced in 1984 establishing a Water Management Board, a Water Management Fund to provide state funding for major projects and required NRDs to prepare groundwater management plans (Aiken 1987). The law also appointed a new Director of Natural Resources, shifting the control of the Natural Resources Commission (the water planning agency of Nebraska) from the local level (as it was dominated by river basin representatives who used to be nominated by the local Natural Resource Districts) to the Governor (subject to confirmation by two-thirds of the National Resources Commission) (ibid.).[114]

During this decade, the 1975 Groundwater Management Act was modified in 1981 (becoming the Groundwater Management and Protection Act) in order to include groundwater quality protection as a specific type of control area designation (Aiken 1987). By law, the state provides that "'every landowner shall be entitled to reasonable and beneficial use of the groundwater underlying his or her land' subject to the provisions of the Nebraska Ground Water Management and Protection Act, and the 'correlative rights of other landowners when the

[113] The 'water hit list' included a cut for example of USD 85 million to the O'Neil Irrigation project in Nebraska (Lewiston Evening Journal, "House rejects second Carter bid to kill water projects", June 16th, 1978, https://news.google.com/newspapers?nid=1913&dat=19780616&id=C2MgAAAAIBAJ&sjid=CWYFAAAAIBAJ&pg=4606,2288036&hl=en (Accessed 28th January 2016). The O'Neil Irrigation project on the Niobrara River was planned as a 77,000-acre irrigation project, including the construction of a dam and a 28-mile diversion canal reaching around 300 farms (The Daily Reporter, "Bedell fights irrigation project in Nebraska", March 26th, 1982, https://news.google.com/newspapers?nid=1907&dat=19820326&id=r2ArAAAAIBAJ&sjid=ltkEAAAAIBAJ&pg=5549,4229715&hl=en, Accessed 28th January 2016).

[114] This doctrine was established in Nebraska in 1933 in the case Olson vs. City of Wahoo (Kelly 2010). Arguments in favour of this move saw the need for a greater control by the Governor of increasing budget appropriations for water development in the state and a need for greater political control (Aiken 1987). Arguments against brought the potential politicization of water development and the weakening of local control over water development policies (Aiken 1987).

ground water supply is insufficient for all users'" (Kelly 2010: 14).[115] In 1978, the Supreme Court in Nebraska ruled that irrigators were liable for damages "in a case of well infringement where the farmer's water use interfered with neighbouring wells providing water for domestic uses" (Peterson et al. 1993: 45). In 1982 the Groundwater Management and Protection Act was further expanded, allowing for the establishment of groundwater management areas as an alternative to groundwater control areas (the difference being that management areas can be established unilaterally by a district after having prepared a groundwater management plan – including an aquifer life goal and a discussion on how controls will be used to attain the goal) (ibid.).[116] During this decade, the development of groundwater management plans under the LB 1106 Law was required for all NRDs where control or management areas had not yet been designated, to be issued by January 1, 1986. Even though, following Aiken (1987: 65), this measure stopped short from imposing effective controls, the requirement for management plans was already a move away from the "traditional local control approach" to groundwater regulation.[117]

By the 1980s however, traditional reclamation policies and the hope of new 'rescue projects' bringing supplemental surface water to compensate for depleting groundwater resources had started to become less realistic (with federal policies having slowed down two water transfer projects in Nebraska) (ibid.). The hope to obtain rescue projects for surface water in order to deal with groundwater depletion had so far allowed irrigators "to resist groundwater controls" and the creation of NRDs (Aiken 1987: 44). During these decades according to Aiken (1987), effective regulation was only developed in the mid-1970s and only 6 hearings had been requested to set up control areas and that only three had been designated by the DWR indicating, following this author, "that the local checks and balances built into the GWMA [groundwater management area] were present". Of the three designated areas, only one adopted regulations "with the potential to significantly extend aquifer life" which reflects "the conservative philosophy that control area designation should be limited to circumstances where controls are truly needed to deal with depletion, and that one state role should be to prevent hasty NRD action in reaction to local groundwater concerns" (Aiken 1987: 45-46).

By 1987 only six control area hearings had been requested and only three were designated by the Department of Water Resources (Aiken 1987). Of those three, only in one, the Upper Republican control area, had adopted regulations "with the potential to significantly extend aquifer life through reduced irrigation withdrawals" (Aiken 1987: 46). In the other areas facing groundwater depletion, irrigators were "looking to the Platte River to supply water for rescue projects to supplement declining groundwater supplies and to forestall imposition of groundwater controls" (ibid.). Following Aiken again, the existence of these legal resorts and the respect for local district management as well as the lure for surface water rescue projects for irrigation created a false sense of security and "combined to create a political climate in which effective controls have been rejected in all but the Upper Republican control area. The hope of developing a rescue project has led to a de facto do-nothing groundwater-management approach in Nebraska, as some irrigators politically resisted imposition of groundwater controls on the ground that the rescue project will extend aquifer life just as groundwater controls would, although in a different fashion" (Aiken 1987: 48).

[115] For a further discussion on Groundwater Management Plans in NRDS, see Section 1.6 and in particular Section 1.6.1.1.

[116] Well drilling moratoria are not allowed in groundwater management plans and well spacing restrictions can be imposed as long as they do not preclude a landowner from continuing to develop irrigation (Aiken 1987).

[117] For a detailed description of the contents of these groundwater management plans, see Section 1.6 and in particular Section 1.6.1.1.

1.4.5 Legislation in the 1990s and 2000s

Following Kelly (2010), the extensive interconnectivity between groundwater and surface water in Nebraska created the necessity to conjunctively manage surface and groundwater management. This necessity became more and more acute as the effects of groundwater abstraction continued to be felt in stream and river flows. In 1998, Kansas filed a complaint with the United States Supreme Court to maintain its share of the Republican River claiming "that Nebraska had violated the Compact by allowing the development of thousands of groundwater wells in hydraulic connection with the Republican River and thereby using more water than its allocation under the Compact" (Zellmer 2008: 400).[118] At the same time, Nebraska claimed that the Compact covered groundwater pumping in the allocation scheme (Sophocleous 2010). The decision from the Supreme Court ruled that groundwater was to be included within the allocation and consumptive use calculations under the compact "because of its close hydrological connection to the river" (Zellmer 2008: 400). This decision provoked both parties to reach an agreement ratified by the Supreme Court in 2003. Key provisions under the agreement include the joint determination under a committee of the amount, timing, and location of depletions from groundwater pumping to the river (Sophocleous 2010; Zellmer 2008). The settlement also established a moratorium on the construction of new wells and regulation of existing ones (Sophocleous 2010).

In 2002, the Nebraska Legislature enacted LB 1003 which created a Water Policy Task Force with the mandate to discuss the integrated management of surface and groundwater and make recommendations regarding desirable water policy changes (Bleed and Hoffman Babbit 2015). Law LB 962 in 2004 intended to mitigate conflicts between surface and groundwater users following the Supreme Court ruling. This law strengthened the provisions of the Groundwater Management Act of 1975 as it required the state through the Department of Natural Resources to undertake a yearly inventory of the river basins and evaluate the long term availability of hydrologically connected water supplies (Sophocleous 2010). Then, in 2004, the role of the DNR was further broadened with new statutory authority "to determine all or portions of river basins as being fully-appropriated" meaning that "the DNR had automatic bans on new wells or surface water appropriations" as it considered the contribution of tributary groundwater to surface water flows and therefore the depletion of groundwater as affecting river basins and adding to the full-appropriation of resources (Aiken 2006).[119]

Following this trend, during the 2014 Legislature, State Senator Lathrop sought to increase state water regulation through an amendment of the LB 1074, to request NRDs "to work with each other and water users to develop basin-wide plans to sustain water resources in every river basin in the state" as, currently, "an NRD manages water use only within its own district, which represents only part of a river basin" (Omaha-World Herald 2014b). The senator’s point of view was that "while some NRDs have taken appropriate steps to sustain groundwater levels and river flows, others have not. If the NRDs cannot devise a basin-wide solution, the state would step in under LB 1074" (ibid.).[120] The amended Bill would require integrated basin management plans with clear goals and objectives with the purpose of sustaining water uses and supply, "ensuring permitted uses of hydrologically connected water will be sustained to the greatest extent possible, and ensuring compact compliance" (Lincoln Journal Star 2014). According to the bill, the goals of these plans would have to be met within 30 years and if they are not, the

[118] See following section for more information on the Republican River Compact.

[119] This will be elaborated in the next section.

[120] See Section Regulation of groundwater and management at the NRD level 1.6 for more details on NRD measures.

Department of Natural Resources would take over. Opposing views to the draft argued that Nebraska's groundwater resources are appropriated at 90 percent and that the serious declines were all experienced prior to 2004 (ibid.).

In the end, Legislature Bill 1098 was passed (48-0) on April the 10th, 2014, restructuring the Nebraska Natural Resources Commission to emphasize water sustainability. This Bill added members to the Commission and created a Water sustainability Fund used to contribute to multiple water supply management goals, increase water productivity and enhance water quality. The Bill introduced also provisions of LB 1074, originally introduced by Senator Lathrop, requiring the development of a basin-wide plan for basins with three or more NRDs, operating under an integral management plan.[121,122]

According to the compromise achieved, the Law stated that basin-wide plans will be developed under consultation and collaboration between representatives from irrigation and reclamation districts, canal companies, groundwater users, livestock owners, the Game and Parks commission, and municipalities that rely on water from the affected area. If an agreement cannot be reached by all parties, the basin-wide plan will be developed by the department. Within 5 years after the adoption of such plan, "the department and affected natural resources districts shall conduct a technical analysis of the actions taken in a river basin to determine the progress towards meeting the goals and objectives of the plan" (NARD 2014).[123] The bill was praised by Senator Christensen, whose district includes most of the Republican River Basin, calling it "a 'great opportunity' for groundwater and surface water users to work together on positive solutions" (Omaha-World Herald 2014c).

1.5 Surface and groundwater interactions in Nebraska: a recurring legal issue

1.5.1 Fully and over-appropriated areas

The connectivity between surface and groundwater is a major management problem in some areas in Nebraska and for a long time the state's surface water law has ignored this phenomenon and the contribution of groundwater to river baseflow (Aiken 2006). The connection between these two resources is however important, as it is estimated that groundwater makes up to 10 to 20 percent of baseflow for the Big Blue, Little Blue, and Republican Rivers and between 50 to 90 percent of the Platte, Loups, Elkhorn, and Niobrara Rivers.[124]

Since the beginning of water management legislation, surface water and groundwater have been allocated based on almost opposite legal doctrines: 'prior appropriation' for surface water

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[121] *Session Review: Natural Resources*, Unicameral Update, May 8th, 2014, http://update.legislature.ne.gov/?p=15714 (Accessed 20th January 2016).

[122] The bill was passed as a compromise, within the background of the compact over the Republican River with Kansas, whose mismanagement "could cause the state to fall out of compliance with an interstate compact", "We're going to have to start writing checks to Kansas [if we mismanage our resources]," he said. "We need to manage it before it goes so far away from us that we can't reel it back in.", *Water Fund and commission restructuring advances*, Unicameral Update, April 9th, 2014, http://update.legislature.ne.gov/?p=15552 (Accessed 20th January 2016).

[123] "The analysis shall include an examination of (i) available supplies, current uses, and changes in long term water availability, (ii) the effects of conservation practices and natural causes, including, but not limited to, drought, and (iii) the effects of the plan in meeting the goal of sustaining a balance between water uses and water supplies. The analysis shall determine if changes or modifications to the basinwide plan are needed to meet the goals and objectives" (NARD 2014).

[124] The difference in contributions, according to Goeke (n.d.), is "a reflection of more overland runoff from the fine textured soils in the Blue and Republican drainages and less overland runoff and much more ground water contributions from the coarse textured sandy soils of the Platte, Loup, Elkhorn, and Niobrara drainages."

(first in time, first in right) and correlative rights (proportional sharing) for groundwater (ibid.). This has had repercussions for Nebraska's river management as well as its transboundary agreements with neighbouring states. According to Bleed and Hoffman Babbit (2015: 35), the split of jurisdictions between the DNR controlling surface water and the NRDs in charge of groundwater was not a major point of discussion when the 1975 Groundwater Management Act was passed, "in part because at the time, decision makers in Nebraska did not appreciate the significance of the hydrologic connection between surface water and groundwater." This separation has caused that "Nebraska water law is on a collision course with reality. For decades Nebraska judges and water policymakers have ignored the hydrologic connection between surface water and tributary groundwater" but "external events […] are forcing Nebraska water policymakers to acknowledge and begin dealing with interrelated surface water and groundwater" (Aiken 2004: 542).

Since then, the State of Nebraska has pushed to recognize the linkages between surface and groundwater and translate them into law and management practices, overcoming decades with two parallel legal management systems for a connected resource (Goeke n.d.). Law 108 in 1996 recognised for the first time the conjunctive use and 'connection of surface and groundwater' and in 2004, Law 962 provided for the effective management of these two hydrologically connected resources through the designation of fully and over-appropriated areas (ibid.). According to Aiken, quoted in the McCook Daily Gazette (2005), this legislation was "one of the most far-reaching water laws in Nebraska history", requiring the State and the NRDs to be "more proactive in anticipating and preventing conflicts between groundwater and surface water users." Law 962 also required the Department of Natural Resources to conduct annual water balance assessments of each watershed or sub-watershed, and instructed to declare each watershed under, fully, or over-appropriated. According to the McCook Daily Gazette (2005), "LB 962 is only the latest development in a two-decade philosophical shift toward a recognition of the interrelationship between surface water and groundwater systems."

The delimitation of boundary limits within which surface and groundwater are hydrologically connected represented a problem as NRDs do not follow aquifer boundaries. The integrated management law required therefore that the state DNR delineate the boundaries through the development of a negotiated rule-making process "to define what areas of the groundwater would be considered as hydrologically connected to the surface water streams" (Bleed and Hoffman Babbitt 2015: 49).[125] Following these authors, the rule became a compromise between reaching a certain level of protection of streams and the practicalities of implementing rules on wells located at some distance from the surface water body "but did not eliminate the problem of groundwater wells adversely impacting surface water users, or vice-versa" (ibid.).

Fully appropriated areas are defined by the Department of Natural Resources when the "long term supply of hydrologically connected groundwater and surface water in the basin would not be sufficient to support new uses without negatively affecting existing uses. When making a determination, DNR will examine stream flows, existing groundwater and surface uses and analyse the future lag effects of existing groundwater uses. The geographic area of the basin considered *fully appropriated* would be limited to the hydrologically connected area and would likely encompass portions of an NRD, not the full NRD" (Water Center 2004: 1). Fully appropriated areas are defined following a 10-50 modelled line (Goeke n.d.), that is, the line

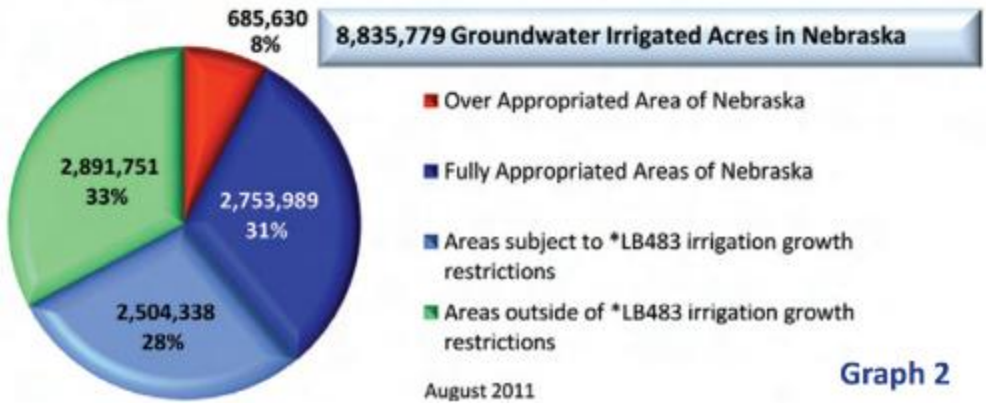
[125] The DNR preliminary considers as such "the area within which pumping of a well for 50 years will deplete the river or a base flow tributary thereof by at least 10 percent of the amount pumped in that time" (Bleed and Hoffman Babbitt 2015: 49).

defining the area where pumping from one well for 50 years would affect stream baseflow by 10 percent or more (ibid.).

Over-appropriated areas are defined following the same model, which defined the line 28-40 as the over-appropriated line. This 28-40 line defines the area where pumping a well for 40 years would affect stream baseflow by 28 percent or more. "Over-appropriated indicates that 28 percent is a significant impact and 40 years is a relatively short period in which to realize such an impact" (ibid.). According to the Director of the Nebraska Department of Natural Resources, over-appropriated areas are considered 'out of balance', with more water taken out of the ground than is being recharged (The Grand Island Independent 2006).

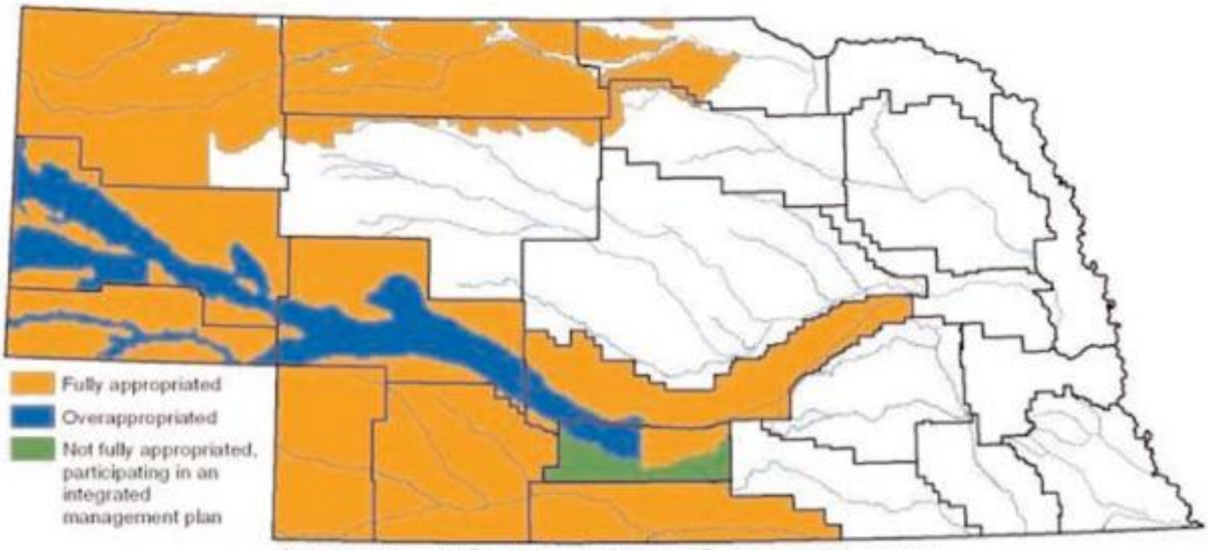
The regulatory consequences of declaring areas fully or over-appropriated are relevant, as defined by Law 962. In over-appropriated areas no new irrigated areas can be added and in fully appropriated areas, new irrigated land can be added only in proportion to irrigated areas being retired. It is the Department of Natural Resources who determines which areas are fully or over appropriated. The affected NRD and the DNR will then develop an integrated surface and groundwater management plan (ibid.). The integrated plan can develop voluntary measures as well as regulatory ones (e.g. allocations of groundwater withdrawals, rotation of use, and reduction of irrigated area) and proposing surface and groundwater controls "that when considered with any applicable incentive programs are sufficient to both ensure the state will remain in compliance with applicable state and federal laws and with any applicable interstate water compact, decree or amendment, and protect groundwater users whose wells are dependent on recharge from the stream and surface water appropriators on such stream from stream flow depletions caused by surface and groundwater uses" (Bleed and Hoffman Babbitt 2015: 38). Presently, there is only part of one river basin fully appropriated, the Platte River.

Figure 49. Groundwater irrigated acres according to type of area



Source: Blueprint 2012.

Figure 50. Fully and over appropriated areas in Nebraska (2008)



Note: In orange: fully appropriated; in blue: over-appropriated; in green: not fully appropriated, participating in an integrated management plan.
Source: Nebraska Department of Natural Resources, in Thompson and Johnson 2012.

1.5.2 The Republican River Compact and surface/groundwater allocations

The interconnectivity of surface and groundwater in Nebraska, combined with the river compact for the Republican River Basin (RRB) emphasises the importance of conjunctive use and shared management and regulation of groundwater and surface water in Nebraska as groundwater forms the baseflow of more than half of the streams in the state (Kishiyama 2006). The issue of the impact of groundwater on surface water arose within the boundaries of the agreement over the Republican River Compact (signed in 1943) where it has been estimated that groundwater pumping contributes about 14 to 18 percent to stream depletion (Kelly 2010). After it was signed, the Compact operated without problems until the 1980s, when Kansas began to express its concern. Some surface water rights holders have seen their rights curtailed following the declaration of full appropriation of parts of the basin despite the fact that these rights precede groundwater pumping (ibid.). Surface water users have started using different strategies to resolve the issue, such as administrative proceedings, litigation, and seeking new legislation (ibid.).

Following decades of litigation, in 2002 the Supreme Court decided that groundwater pumping by Nebraska farmers in the RRB reduced the availability of instream flows to downstream users in Kansas and that Nebraska was using more water than its allocation under the compact. The Compact allocated different volumes and river flows for each of the countries, with 234,500 acre-feet of water to be derived from the Compact for Nebraska. As a result groundwater management districts in Nebraska were required to introduce a variety of agricultural water use restrictions to reduce their impacts on stream flow. A moratorium on new wells was extended across the fully allocated areas; this effectively removed the future option to irrigate land that was currently in dryland production. Annual volumetric restrictions were placed on all existing wells, based on certification of historical irrigated area, and well metering was completed in the Nebraska portion of the RRB (Savage and Ifft 2013: 4).

Prior to the litigation, the Republican River Compact Administration's Engineering Committee had already expressed its concern regarding groundwater development in the basin in 1985, and called for a well moratorium in alluvial aquifers. In response, the member from Nebraska "stated, correctly, that he had no authority under Nebraska law to put such a moratorium in place. As a result of that continuing impasse, the RRCCA was never able to resolve this issue" (McKusick 2003: 40). With the Final Settlement Stipulation, the issue was settled as a wide moratorium for wells was imposed in Nebraska upstream of Guide Rock dam (with several exceptions)[126] and the affected NRDs in Nebraska had adopted temporary rules to make the moratorium immediately effective (McKusick 2003).

According to the special Master from the Supreme Court, "the process that led to adoption of these rules demonstrates the good faith cooperation of the States in achieving the Final Settlement Stipulation. According to David Cookson, Counsel of Record for Nebraska: 'as part of the agreement with the other States, we had agreed… in the Agreement in Principle [April 2002] to have these particular suspensions and [the] moratorium in place by the time the final settlement agreement was submitted… To do that, each of the NRDs under the Groundwater Management and Protection Act, had to ask the Department of Natural Resources to resume a study under that Act that had begun prior to the filling of the litigation, but which had been suspended during the pendency of the litigation" (McKusick 2003: 41).

During that time, there were contentious public hearings in two NRDs as they published the new rules and regulations adopting the temporary suspension of wells (the Middle Republican and Lower Republican NRDs). The board meetings in the end voted the rules unanimously for the Middle Republican NRD and by 10 votes against 1 in the Lower Republican NRD (McKusick 2003). Compact Compliance was agreed to be monitored through a new groundwater modeling to determine the amount, timing, and location of depletions as well as revise the Compact Accounting Formulas to include all depletions caused by groundwater pumping. Allocations to each of the states will be adjusted if the 'virgin water' supply of any sub-basin is determined to vary by more than 10 percent from the amount originally set by the Compact (ibid.). Following the settlement however, "large increases in the number of wells in the Republican River Basin NRDs in Nebraska prior to the moratorium can be expected to cause additional violations of the agreement by Nebraska without additional regulation of existing wells" (Popelka 2004 in Patent 2008: 18). In 2004, Nebraska addressed water management concerns with Legislative Bill 962, intended to address the settlement agreement for the Republican River Compact. The legislation altered the statutes regulating inter and intra basin transfers of water rights and extended the deadlines for cancellation of water rights (Patent 2008). It also required NRDs to maintain groundwater management plans (including groundwater reservoir information, recharge rates, water data collection programs, past-present-projected water use). The law also allowed NRDs to raise taxes for administration and implementation of these measures (ibid.). The law also gave new responsibilities to the Department of Natural Resources beginning in 2006. The Department had to create a report of availability of water supplies in each basin and will classify them as fully or over-appropriated (see below) (ibid.).

[126] These exceptions, considered 'reasonable and sensible' by the Supreme Court, and include "certain areas in five Nebraska counties where return flows from nearby Platte River basin irrigation have actually raised the groundwater table in the Republican River Basin and contributed to stream flow therein; […] replacement wells without increased water consumption; […] wells to which a water right or permit is transferred; wells for the expansion of municipal and industrial uses; augmentation wells, i.e., wells acquired or constructed for the sole purpose of offsetting stream depletions in order to comply with Compact allocations" (McKusick 2003: 44-45).

In 2005, the Nebraska Supreme Court in its *Spear T Ranch v. Knaub* ruling gave judicial recognition to the reality of groundwater and surface water interconnectivity, thus erasing their legal separation for the first time (Kishiyama 2006). Later that decade, Legislative Bill 701 in May 2007 allowed the NRDs from the Republican River Basin to lease surface or groundwater rights in the basin to irrigators or purchase the rights by issuing water bonds with funds raised through property taxes levied by the NRDs on the residents in the basin.[127] The aim of this bill was to increase the amount of water left in the Republican River reaching Kansas[128] and an additional attempt by the state legislature to comply with the Republican River Compact (Patent 2008).

1.6 Regulation of groundwater and management at the NRD level

NRDs are a natural resource multi-use management entities set up to manage and protect Nebraska's natural resources. Nebraska's NRDs are funded through property tax, both rural and urban. Funding for NRDs from property taxes can vary. According to John Turnbull, Manager of the Upper Big Blue NRD, "the Upper Big Blue Natural Resource District, the property tax amounts to about half or 60 percent of our annual revenue. The rest comes from grants and outside monies working with other agencies for projects. […] The property tax amounts to about one and a half percent of an individual's property tax whether its farmland or property in town."[129]

The legislature elaborated in Chapter 46, Article 7 of the Groundwater Management and Protection Act, established that "the goal [of groundwater management] shall be to extend ground water reservoir life to the greatest extent practicable consistent with reasonable and beneficial use of the ground water and best management practices" (Department of Natural Resources 2014: 1). However, before 2004, most NRDs in Nebraska were not fully exercising their charges under the Groundwater Management and Protection Act, not actively regulating groundwater development or use. Only one, the Upper Republican NRD restricted well drilling and groundwater abstraction for over 30 years (Kelly 2010).[130]

In the past, NRDs have preferred a combination of approaches to manage groundwater resources, but mostly focusing on educational and voluntary efforts (Aiken 1980; LPSNRD 1995). The Lower Platte South NRD described in 1995 how historically it utilized primarily non-regulatory approaches "including: public education; encouragement of voluntary use of best management practices; governmental inter-agency coordination; monitoring to identify water quality and quantity problems; and inspection and demonstration (training) programs. […] Where problems arise the LPS NRD will first offer additional cost-sharing incentives and accelerate information and education activities in the affected area. If problems continue to worsen regulations will be implemented to protect the groundwater resource" (LPSNRD 1995: 51).

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[127] The bonds issued by NRDs "are authorized only to pay for acquisition by purchase or lease of water rights or storage of water rights, acquisition by purchase or lease or management of canals or reservoirs, vegetation management, or augmentation of river flows" (Patent 2008: 23). Bonds would be paid by adopting a property tax for taxpayers within the Republican River Basin, and an occupation tax for NRDs to use as a way to raise money to pay bond principals and interests (levied annually on all irrigated acres within the District) (Patent 2008).

[128] According to Vogel (2008: 15) this legislation is unconstitutional as, "by granting Republican River NRDs the authority to levy a property tax in order to comply with the compact, the state is in fact levying a property tax to achieve a state goal in violation of the Nebraska Constitution" which states that "The state shall be prohibited from levying a property tax for state purposes" (Article IIIV, section 1A, Nebraska Constitution) (Vogel 2008: 17).

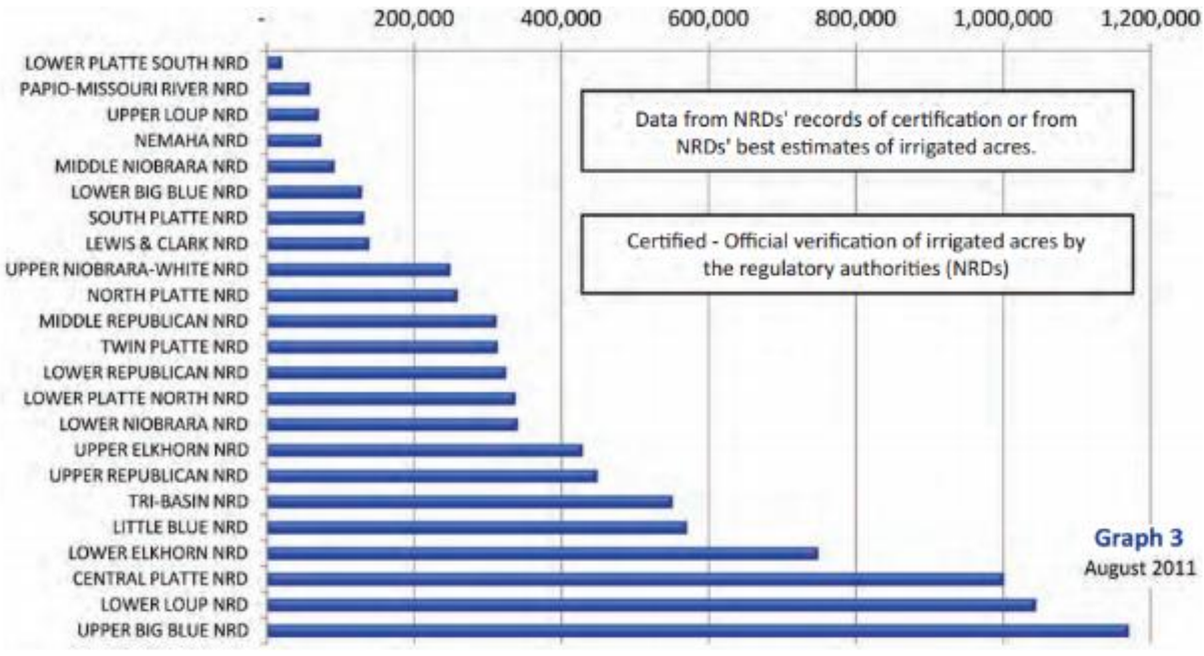
[129] Ganzel, B. 2006 "Nebraska's unique Natural Resource Districts", Interview with John Turnbull, http://www.livinghistoryfarm.org/farminginthe50s/movies/turnbull_water_11.html, Accessed 18th January 2016.

[130] See sections below with more information on the Upper Republican NRD.

Rules are enacted through the NRDs' broad powers, which give them a "distinctive advantage over similar districts in other states that rely on local control" (Kelly 2010: 15). Despite that, for many years all but one NRD in Nebraska had not fully developed their expected management and regulation prerogatives under the Groundwater Management and Protection Act. Moreover, as will be described later, only one NRD, the Upper Republican NRD had defined a set of rules for groundwater use in a control area to address groundwater over-abstraction 20 years after the enactment of the Groundwater Management Act (Kelly 2010).

Any person violating the rules and powers of an NRD is subject to a civil penalty overseen by the courts. The Department of Natural Resources defines the penalty "of not less than one thousand dollars and not more than five thousand dollars for each day an intentional violation occurs. In assessing the amount of the civil penalty, the court shall consider the degree and extent of the violation, the size of the operation, whether the violator has been previously convicted or subjected to a civil penalty under this section, and any economic benefit derived from noncompliance. Any civil penalty assessed and unpaid shall constitute a debt to the state which may be collected in the manner of a lien foreclosure or sued for and recovered in a proper form of action in the name of the state in the district court of the county in which the violator resides or owns property. The court shall, within thirty days after receipt, remit the civil penalty to the State Treasurer for credit to the permanent school fund.

Figure 51. Groundwater irrigated acres listed per NRD



Source: Blueprint 2012.

1.6.1 Groundwater regulatory tools for NRDs

In order to enforce the Nebraska Groundwater Management and Protection Act, a district can require its users to report water uses and irrigated acres (landowners and others with control over the water uses and irrigated acres) for the purpose of issuing certifications. NRDs can also require meters to be placed in wells, and impose an immediate temporary freeze of 180 days on the construction of any new water well and on any increase in the number of acres historically irrigated without prior notice or hearing, only following a resolution from the Board (Department of Natural Resources 2014).

Also, each NRD will adopt, following a public hearing, "rules and regulations necessary to control or prohibit surface runoff of water derived from ground water irrigation" (Department of Natural Resources 2014: 9). According to the Department of Natural Resources, these rules will prescribe "(a) standards and criteria delineating what constitutes the inefficient or improper runoff of ground water used in irrigation, (b) procedures to prevent, control, and abate such runoff, (c) measures for the construction, modification, extension, or operation of remedial measures to prevent, control, or abate runoff of ground water used in irrigation, and (d) procedures for the enforcement of this section" (ibid.). The objective of these rules is to extend groundwater reservoir life and conserve groundwater supplies, meeting the requirements of the Nebraska Groundwater Management and Protection Act of 1975.

Each NRD will maintain a groundwater management plan. The plan will include, to the extent possible (not limited to and if available) information on groundwater supplies, local recharge characteristics, groundwater quality concerns, proposed conservation and augmentation supply programs, groundwater management objectives (including a proposed groundwater reservoir life goal for the district, with information provided by the Department of Natural Resources).[131] Groundwater management plans will be reviewed by the Director of Natural Resources to ensure that "the best available studies, data, and information, whether previously existing or newly initiated, were utilized and considered and that such plan is supported by and is a reasonable application of such information" (Department of Natural Resources 2014: 11).

1.6.1.1 Groundwater management areas

The institutional history of groundwater management varies by NRD and also depends on the surface of land under irrigation with groundwater (Figure 51). The NRD can declare a Groundwater Management Area where it can impose pumping restrictions, temporary well moratoria, measurements of groundwater use and, in some cases, a reduction in irrigated acreage (Kelly 2010). NRDs can establish groundwater management areas to accomplish some of the following objectives: "(a) Protection of ground water quantity; (b) protection of ground water quality; or (c) prevention or resolution of conflicts between users of ground water and appropriators of surface water, which ground water and surface water are hydrologically connected" (Department of Natural Resources 2014: 11).

Groundwater Management Areas are designated at the request of the NRD but only after the approval of the state's Department of Natural Resources. The groundwater management area

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[131] As defined by the Department of Natural Resources, groundwater management plans will include (not limited to): "(1) Groundwater supplies, saturated thickness maps, and other ground water reservoir information; (2) Local recharge characteristics and rates from any sources; (3) Average annual precipitation and the variations within the district; (4) Crop water needs; (5) Current groundwater data-collection programs; (6) Past, present, and potential ground water use within the district; (7) Ground water quality concerns within the district; (8) Proposed water conservation and supply augmentation programs for the district; (9) The availability of supplemental water supplies, including the opportunity for ground water recharge; (10) The opportunity to integrate and coordinate the use of water from different sources of supply; (11) Ground water management objectives, including a proposed ground water reservoir life goal for the district. For management plans adopted or revised after July 19, 1996, the ground water management objectives may include any proposed integrated management objectives for hydrologically connected ground water and surface water supplies but a management plan does not have to be revised prior to the adoption or implementation of an integrated management plan pursuant to section 46-718 or 46-719; (12) Existing sub-irrigation uses within the district; (13) The relative economic value of different uses of ground water proposed or existing within the district; and (14) The geographic and stratigraphic boundaries of any proposed management area" (Department of Natural Resources 2014: 9).

will be finally and officially designated by the Department if it concludes, after a public hearing, "that the uncontrolled development and use of ground water has caused or is likely to cause an inadequate ground water supply to meet present or reasonably foreseeable needs" (Aiken 1987: 45). [132] According to this author, the need for departmental approval reflected "the conservative philosophy that control area designation should be limited to circumstances where controls are truly needed to deal with depletion" and prevent hasty local actions in reaction only to local concerns (Aiken 1987: 46). According to Peterson et al. (1993), the provisions authorizing the state to designate control areas unilaterally were removed from the bill during the debate in parliament in 1969. If the request is approved, the NRD can set up specific regulations to set access limits to the aquifer within the control area such as a well drilling moratorium[133] or well-spacing requirements[134] (Stephenson 1996).

At the public hearing, a series of individuals will testify (e.g. including NRD representatives, Conservation and Survey division, the public). If, as a result of the hearing, the Department favours the establishment of the control area, the boundaries are outlined in consultation with the NRD. However, if the Department "feels that a ground-water control area is not warranted, it can refuse to make that designation regardless of the wishes of the NRD. The Department's sole consideration in determining whether a control area should be established is whether the ground-water supply is adequate to meet present or reasonably foreseeable future needs" (Fricke and Pederson 1980: 547). The law qualified that the adequacy of supply be evaluated following: 1) conflicts between users; 2) substantial economic hardship existing or that may occur as a result of groundwater decline; 3) other conditions existing that indicate the inadequacy of groundwater supply. A public hearing needs to be held after the declaration of 'control area' so that the NRD board can present potential rules to its members. These regulations will be approved by the DWR before they become effective. If the necessary controls are not adopted by the NRD after a year of the declaration, the Department of Natural Resources will impose groundwater regulations (Fricke and Pederson 1980).

When the Groundwater Management area has been declared, "[w]ithin one hundred eighty days after the designation of a management area or the requiring of an action plan for a management area, a purpose of which is protection of water quality, the district or districts within whose boundaries the area is located shall prepare an action plan designed to stabilize or reduce the level and prevent the increase or spread of ground water contamination. Whenever a management area or the affected area of such a management area encompasses portions of two or more districts, the responsibilities and authorities delegated in this section shall be

[132] "If a management area is proposed and the primary purpose of the proposed management area is protection of water quality, the director shall consult with the Department of Environmental Quality regarding approval or denial of the management plan. The director shall consult with the Conservation and Survey Division of the University of Nebraska and such other state or federal agencies the director shall deem necessary, when reviewing plans. Within ninety days after receipt of a plan, the director shall transmit his or her specific findings, conclusions, and reasons for approval or disapproval to the district submitting the plan. If the Director of Natural Resources disapproves a ground water management plan, the district which submitted the plan shall, in order to establish a management area, submit to the director either the original or a revised plan with an explanation of how the original or revised plan addresses the issues raised by the director in his or her reasons for disapproval. Once a district has submitted an explanation pursuant to this section, such district may proceed to schedule a hearing pursuant to section 46-712." (Department of Natural Resources 2014: 11).

[133] As considered by Stephenson, a well-moratorium is seen as the last resource and considered constitutionally suspect under the state's reasonable use doctrine as it would undermine the right of users to access, a constitutionally vested right "that cannot be taken away without payment of compensation" (Nebraska Natural Resource Commission 1983 in Stephenson 1996: 764).

[134] Well spacing requirements were defined in 1957 already, located at least 600 feet from another irrigation well. The distance between irrigation wells and industrial or public water supply well was established at 1,000 feet (Aiken 1980).

exercised jointly and uniformly by agreement of the respective boards of all districts so affected" (Department of Natural Resources 2014: 34).

Each district where a groundwater management area has been designated "or an action plan for a management area has been required pursuant to section 46-725 shall, in cooperation with the Department of Environmental Quality, establish a program to monitor the quality of the ground water in the area and shall if appropriate provide each landowner or operator of an irrigation system with current information available with respect to fertilizer and chemical usage for the specific soil types present and cropping patterns used" (Department of Natural Resources 2014: 35). Each management unit will have a different water level objective and the objective for each unit will be to “maintain a stable long term water level condition that is now increasing or decreasing” (CPNRD 2015, pers. com.).

Allocation of groundwater in a management area is regulated via permissible withdrawal levels of groundwater defined for each irrigated acre (in general, these are to be allocated equally). The allocation will specify the total number of acre-inches allocated per irrigated acre each year (except in the case an NRD may allow a user to average allocations over a different period of time) (Department of Natural Resources 2014). The Lower Platte South NRD for instance defined in its management plan of 1995 five separate 'groundwater reservoirs' (LPSNRD 1995). Each of these five areas is managed separately with a monitoring network and a set amount of decline serving as a trigger for a specific set of actions to be applied (at the consideration of the NRD). In the Central Platte NRD, “if water levels decrease year after year and reach 50 percent of the acceptable drawdown [the NRD] uses a phased approach to cut back irrigated areas” (CPNRD 2016, pers. com.). In this same NRD pumping is not controlled directly through the groundwater management plan, only irrigated land, crop water use, and new well locations.[135] “Producers have certified what lands they are irrigating and we [the NRD] collect aerial imagery each year to check compliance” (ibid.).

Upon the establishment of the groundwater management area in the Lower Platte South NRD, the entire NRD was put under Phase 1 in 1997 and remains designated at Phase 1. The trigger for Phase 2 was defined (in 8 management areas) when the spring static water level elevations in 30 percent of monitoring wells declined from the established upper elevation of the saturated thickness to a certain percentage in elevation reduction and remain below that elevation for two consecutive years (it was defined as 8 percent reduction for all areas except one, at 15 percent). Phase 3 (established for only one management area) is triggered when spring static water level elevations in 50 percent of the NRD’s monitoring wells in that designated area have declined below 15 percent (except for one area, with a trigger set at 30 percent) (LPSNRD 1995).

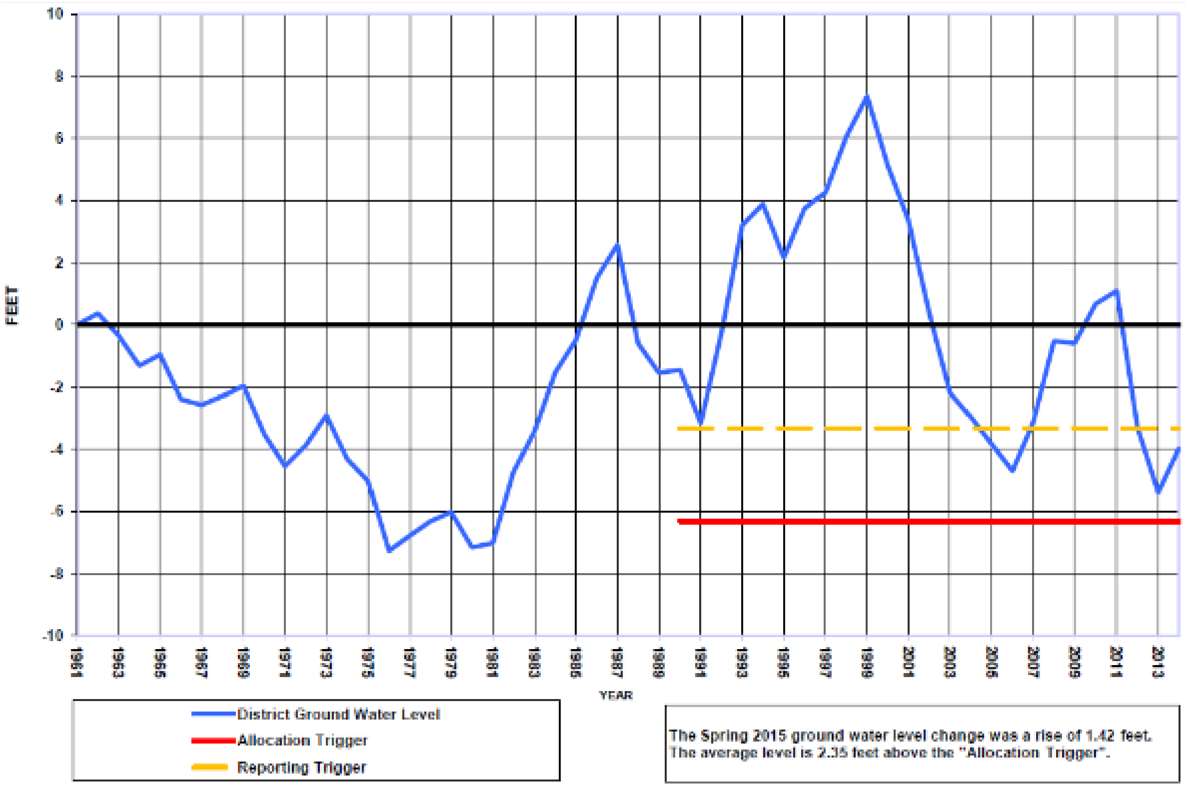
Phase 2 triggers a set of actions to be implemented by the NRD. These included a cost-share program to implement Best Management Practices such as irrigation scheduling, land treatment, irrigation surge, pivot conversions, water return lines, proper chemigation and fertigation techniques, crop rotation, reuse systems, and water use efficiency techniques. It also included flow meters for all wells, and educational certification programs. Phase 3 triggered the following actions established by the management plan, on top of the actions from Phase 1 and

[135] The Central Platte NRD also works “with watershed, groundwater, and surface water models to better understand the area water budgets and analyse future water management scenarios” (CPNRD 2016, pers. com.). Much of the district’s irrigated land is in the Platte Valley with shallow groundwater depths and important recharge to the aquifer from irrigation overflow (ibid.).

2: well spacing requirements, allocating the annual permissible withdrawal of groundwater, rotating the use of groundwater, reduction of irrigated areas.

The Upper Big Blue NRD[136] established a Groundwater Management Area for quantity control purposes in 1977 in response to concerns regarding declining groundwater levels. This management area makes provisions for metering, allocation, and other controls if average groundwater levels fall below pre-established allocation triggers, defined as the 1978 groundwater level (slightly above the historic all-time low level recorded in 1976). Two triggers were established, the first one being the 'reporting trigger' set at 3 feet above the 1978 level. This first trigger establishes that high capacity well users are required to report water uses and certify irrigated areas as well as the number of active wells (Upper Big Blue NRD 2014 and Upper Big Blue NRD website). If groundwater levels fall below 1978 levels (trigger 2), the board of the NRD will set the duration of the use period and allocation amount by September 1st, prior to the start of the groundwater use period. The groundwater allocation level for the first groundwater use period after trigger 2 has been declared is set at 30 inches per certified groundwater use acre. The allocation for the second groundwater use period is set at 45 inches per certified groundwater use acre (Upper Big Blue NRD 2014).

Figure 52. Upper Big Blue average groundwater levels triggers and historic groundwater levels (in feet)



Source: Upper Big Blue NRD 2015.

136 The Upper Big Blue NRD was established in 1977 and has now just under 1.2.million irrigated acres certified by some 12,000 wells, plus an additional 152 municipal wells and 140 industrial wells. Irrigation with groundwater represents 96 percent of all groundwater use in the district. The Upper Big Blue NRD has the largest irrigated area with groundwater in the whole of Nebraska.

1.6.1.2 Well moratoria, meters, and permits

A fully appropriated basin automatically triggers, under LB 962, a moratoria on new surface water rights and on new groundwater wells in areas designated as 'hydrologically connected' with surface water until the development of an approved integrated management plan (Kelly 2010).

The Upper Republican NRD has the longest history of regulation in the state: well metering took place from 1978 to 1982 and volumetric restrictions on pumping were implemented once metering was complete. In the three NRDs in the Republican River Basin (i.e. the Lower Republican NRD, the Middle Republican NRD, and the Upper Republican NRD), groundwater allocations, the temporary suspension of drilling, and the moratorium on drilling occurred all for the first time in Nebraska. This basin was also the only one in Nebraska to have installed meters in all high capacity groundwater wells. The installation of meters in the Lower and Middle Republican NRDs and the Tri-Basin NRD began in 1998 but volumetric restrictions were not put in place until 2004 (Savage and Ifft 2013).

In the portions of the state that overlie the North Platte and Platte River Basins, metering and volumetric restrictions started in over-appropriated sub-basins in 2002 and well drilling moratoria were implemented in 2001. District staff are allowed to enter upon any land after requiring notice as provided by law in order to inspect flow meters. In areas of the state not facing interstate litigation over surface water or not fully allocated, groundwater irrigation wells are not metered and farmers may drill new wells, though all active wells must be registered with the local NRD. All wells must be registered with the local NRD at the time drilling commences (Savage and Ifft 2013: 5-6). NRDs in the Republican Basin have also been utilizing federal programs and partnerships to conserve water, and the basin is the first in the USA to utilize the federal Conservation Reserve Enhancement Program to temporarily retire irrigated acres, with approximately 40,000 acres enrolled in the program for that purpose (NARD 2015).

The Department of Natural Resources specified the procedure to obtain a well permit in the Groundwater Management and Protection Act. Wells designed to pump 50 gallons per minute or less do not require a permit (except for special cases such as a combined well, fire control purposes, livestock watering, or in groundwater management areas with regulations imposed to control declining groundwater levels) (Department of Natural Resources 2014). Users will have to pay a 50 dollar filing fee to the NRD and will have to state the intended location of the well, intended size, type, acreage and location of the land to be irrigated, a description of the proposed use (if other than irrigation purposes) (ibid.).

The Lower Loup NRD is in Phase I of its Groundwater Management Programme requiring for instance that all wells pumping over 50 gallons per minute need to obtain a permit. The Lower Loup NRD has established rules for users intending to drill wells to pump more than five hundred acre feet of groundwater or upgrade existing high pumping capacity wells. Users have to submit information to the district showing the impacts to groundwater and surface water uses (e.g. a hydrologic evaluation, showing impacts on water quantity and quality currently and in 20 years' time). The District also required the certification of irrigated acres by January the 1st, 2008. The certification of acres is required for land "capable of being supplied with groundwater or surface water through irrigation works at the time of certification if certified prior to January 1, 2008 or had been irrigated at least 2 out of 10 years prior to January 1, 2008." (Lower Loup NRD 2015: 20). Flow meters have to be installed in all water wells for irrigation purposes and the NRD may seal them to prevent tampering. Users have to notify the NRD prior to changing the location of the meter and it is the responsibility of the NRD to provide for service and maintenance of the meter according to manufacturer standards. The maintenance of the flow meter is to be done by the owner.

Nebraska also controls wells through a system of metering. However, the metering of wells is not homogenous across the state (metering in the North Platte and Platte basin started in 2002, compared with the Upper Republican NRD where metering took place from 1978 to 1982 (Savage and Ifft 2013)). In areas of the state not facing litigation or allocation conflicts over surface water due to full or over-appropriation of water rights (e.g. the Republican River Basin shared between Colorado, Kansas, and Nebraska), irrigation wells do not have to be metered (ibid.). All wells however must be registered at the NRD 30 days after being drilled. The Department of Water Resources maintains an active well database for the state (although data once the well has been registered is not updated, and no further information is entered on specific well yields or changes and water levels) (ibid.).

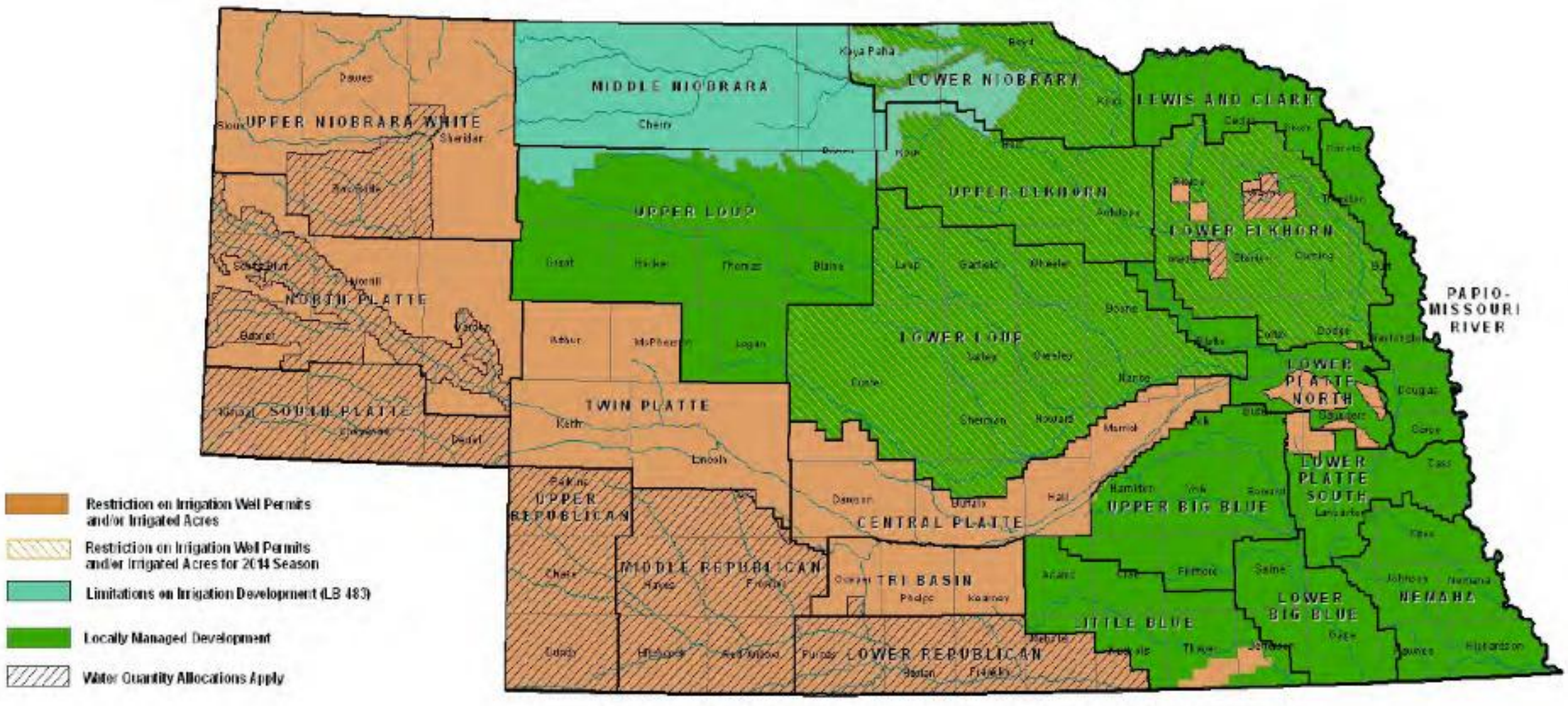
Table 8. NRD groundwater regulations across Nebraska

NRD	Allocation	Flow meters	Well drilling moratorium	Required water use reports
Upper Niobrara White	Yes 54"/4 years	Yes	Yes	Yes
Middle Niobrara	No	Yes (in sub-area)	Yes (in sub-area)	Yes (in sub-area)
Lower Niobrara	No	Yes (new wells)	Yes	Yes (in sub-area)
North Platte	Yes 70"/5 years (Pumpking creek = 36"/3 years)	Yes (in over-appropriated and Pumpkin Creek areas)	Yes	Yes
South Platte	Yes 42"-54"/3 years by sub-area	Yes	Yes	Yes
Twin Platte	No	No	Yes	No
Central Platte	No	No	Yes	Yes
Lower Platte North	Yes 27"/3 years in sub areas	Yes (in sub-areas)	Yes (in sub-areas)	Volunteer
Lower Platte South	Yes 21"/3 years 9"/ 1 year maximum in North-west sub-area	Yes	Yes (in North-west sub-area)	Yes
Upper Loup	No	Yes (new wells)	Yes (in sub-areas plus limited acre expansion)	Yes
Lower Loup	No	Yes	Yes	Yes (in sub-areas)
Upper Republican	Yes 65"/5 years	Yes	Yes	Yes
Middle Republican	Yes 60"/5 years	Yes	Yes	Yes
Lower Republican	Yes 45"/5 years	Yes	Yes	Yes
Tri-Basin	Yes 27"/3 years (in sub-areas)	Yes (in Republican Basin)	Yes	Yes
Little Blue	No	No	Yes (in sub-area)	Volunteer
Upper Big Blue	Yes When triggered 30'/3 years then 45"/5 years	Yes (new wells) and then all wells by 1/1/2016 (or if trigger hits first)	No	Yes

Lower Big Blue	Set when triggered	Yes (new wells)	No	Yes
Upper Elkhorn	No	Yes	Yes (on new irrigated acres for 2014)	Yes
Lower Elkhorn	Yes 13"-14"/1 year (in sub-areas)	Yes (new wells) Yes (all wells in sub-areas)	Yes (plus no new irrigated acre development)	Yes
Lewis & Clark	No	No	No	Yes (in sub-areas)
Papio-Missouri River	No	No	Yes (in sub-areas)	No
Nemaha	No	Yes (new wells)	No	Yes

Source: Based on Map on NRD Groundwater Regulations across Nebraska (February 2014), Central Platte NRD, http://cpnrd.org/wp-content/uploads/2015/11/2014-STATE-MAP-WATER-MANAGEMENT-STATUS.pdf (Accessed 28th January 2016).

Figure 53. Restrictions on groundwater irrigation (2013)



Note: in orange: restrictions on irrigation well permits and/or irrigated acres; yellow dashed: restrictions on irrigation well permits and/or irrigated acres for 2014 season; in light blue: limitations on irrigation development (LB 483); green: locally managed development; blue dashed: water quantity allocations apply.
Source: NARD 2013.

1.6.2 Groundwater allocation plans in the Upper Republican NRD

The Upper Republican NRD, in the south-western corner of Nebraska, has a total area of 1.73 million acres of which 425,000 are irrigated (mostly with groundwater). There are 3,556 wells inventoried and a population of around 9,000 inhabitants. The Upper Republican NRD was the first to enact groundwater use and access restrictions after having requested the designation of 'control area' (the name for groundwater management areas previously) in view of declining water levels in irrigation wells as early as the 1970s. The control area was approved in 1977 (covering an area of around 6,700 km2 and an estimated 2,400 wells) and the rules to control groundwater were approved in 1978 (Fricke and Pederson 1980). The Upper Republican NRD passed rules to limit access to groundwater setting up well spacing requirements, (one kilometre between wells, limited to certain critical areas) (Stephenson 1996).[137] This was the first instance in Nebraska of water-use restrictions on agricultural groundwater use. At the time, the Board of the Upper Republican NRD considered imposing a well moratorium on several occasions, constitutional questions and well driller opposition eliminated the option (ibid.).

The District also required its users to install meters by April 1980 on wells abstracting more than 6.3 litres per second (the first area on the High Plains to require well meters on all irrigation wells).[138] The District also established quantitative limitations on withdrawals based on the total amount of groundwater to be abstracted based on the total depth of water that can be applied on each acre irrigated – established at 15 inches of water for a given year (ibid.). The district granted flexibility however as the per-acre allocation was to be summed over a five-year period (users were allowed to pump a maximum of 75 inches over 5 years with no restrictions as to when or how they are allocated over the five year period) (ibid.).[139]

Currently, for the Upper Republican NRD, the established allocation for 2013-2017 is a total of 65 inches (13 per year). According to the Management Plan, water users can distribute use of the 65 inches over the five-year period as they wish so long as the 65 inch allocation is not exceeded. The district however enacted new rules in 2013 with the objective to reduce water use. Regulation changes limited "to 7.5 inches the amount of unused allocation from previous allocation periods that can be used in a current allocation period without incurring a penalty" (NARD 2015: 2). The new rules also prohibited to borrow groundwater allocations from upcoming periods. This measure is expected to reduce water use by approximately 90,000 acre feet over the allocation period.

[137] These critical areas were identified as areas where the annual rate of aquifer level decline exceeded one percent per year. A third of the Natural Resource District was classified as critical that same year (Stephenson 1996).

[138] These meters are currently controlled once a year by NRD staff. Upper Republican River NRD, http://www.ncorpe.org/compliance (Accessed 28th February 2016).

[139] After trials between 1980 and 1982, the first 5-year limit was set up in 1983 allowing 80 inches of groundwater to be pumped per acre for centre pivots (16 inches per year). The following two 5-year periods saw the rule tightened with a limit of 75 inches and 72.5 inches respectively. Allocations were set for the District not to achieve a “specified aquifer life goal” but “so that a farmer using sound water management practices could continuously grow corn” (Stephenson 1996: 769). Groundwater users were allowed to carry-over unused water from one allocation period to the next and to combine allocations from different wells (as long as the combined allocation does not exceed the total allowed) (ibid.).

The analysis of the results of these measures is mixed. In the Upper Republican NRD, groundwater allocations and water-saving technologies have, according to the Nebraska Association of Resource Districts (NARD), incentivized the use of less groundwater during some weather conditions. "From Spring 2009 to Spring 2012, groundwater levels rose an average of 1.3 feet in the District, the largest increase in groundwater levels during a period with consecutive increases. Precipitation levels from 1980-1983 were similar to 2009-Spring 2012, yet the average amount of water applied per acre was approximately 10 percent less than the early 1980s. Despite reduced water applications, irrigated corn yields during the recent period were approximately 25 percent higher, on average, than the early 1980s" (NARD 2015: 2).

According to the NARD again, the positive effects are quantifiable, with an average change in groundwater levels "approximately 60 percent less than what was predicted would occur since the 1970's without restrictions" and with the most significant groundwater level declines being "approximately half of the 1970's estimates." Also, "approximately half of the average groundwater decline in the District occurred in the 10 years before allocations were established" (NARD 2015: 2). However, even if Stephenson (1996) considered that following these rules well drilling was reduced drastically in the following 15 years (combined with high interest rates and increasing pumping costs due to groundwater depletion and low commodity prices in the 1980s), the NRD continued to implement rules and groundwater levels continued to decrease over the years (Figure 46), despite the 'aggressiveness' of the District as Stephenson (1996) put it.

Even with a booming economy in the 1990s, the District tightened water abstraction criteria to one half of one percent of decline of saturated thickness in 1991 and in 1992 to one fourth of one percent. The minimum well spacing in critical areas was further increased from one kilometer to one mile in 1992 (ibid.). With increasing high commodity prices in the 1990s and above average rainfall, the district feared further increases in groundwater abstraction, threatening to undermine, as Stephenson (1996: 768) put it, "the system to limit access", and in February 1997 the Upper Republican Natural Resource District established the first well moratorium in Nebraska. Also, besides its regulatory actions, the Upper Republican NRD has been retiring previously irrigated acres of land to help preserve groundwater. These retired areas are close to streams in order to reduce stream depletion caused by pumping. Through a partnership with the Natural Resources Conservation Service, the district spent USD 2.1 million in land purchases from willing sellers easements for 1,546 acres (NARD 2015).

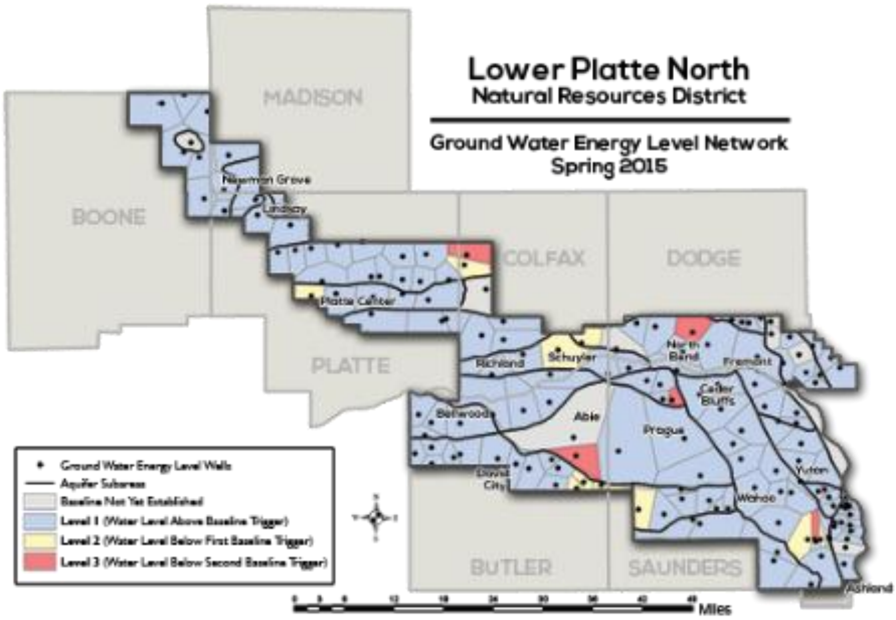
1.6.3 Controlling groundwater levels in the Lower Platte North NRD[140]

The Lower Platte North NRD controls groundwater levels through a monitoring network of wells measured twice a year (in the fall and in the spring). The district has also several monitoring wells continually logging groundwater levels. The NRD defined 1987 as the 'base year' for monitoring long-term groundwater level trends (chosen as it followed several years of rainfall above normal and recharged aquifers to near 'pre-development' years). The NRD has defined three types of areas to characterize groundwater levels (Figure 54): 1) Blue areas are "Level 1" where water levels are within historical norms

[140] Source for this sub-section: Groundwater levels in the Lower Platte, http://www.lpnnrd.org/projects/water/monitoring.html#gwlevels (Accessed 18th January 2016).

compared to the base year; 2) Yellow areas are "Level 2" areas, where water levels in the aquifer have declined approximately 10 percent since 1987; and 3) Red areas are "Level 3" areas, where water levels in the aquifer have declined approximately 15 percent since 1987. Grey areas are areas where the NRD is still gathering data to establish a baseline. Trigger levels for groundwater management have been defined depending on the type of aquifer: confined or unconfined (Table 9). At present (January 2016), the district is considered at Level 1, with all users required to be certified every four years.

Figure 54. Characterisation of groundwater levels in the Lower Platte North NRD



Source: Lower Platte North NRD.

The Lower Platte North NRD defined three major types of water development area: 1) the non-hydrologically connected areas with up to 1,000 new irrigated acres per year which can be developed every year; 2) the hydrologically connected areas with up to 2,500 new irrigated acres per year to be developed every year; 3) restricted development areas with no new irrigated acres or water use allowed. The increase in irrigated land surface has to be applied by each user through a 'variance request'. Variance request are reviewed by the NRD and a limited number of applications is approved every September Board meeting. The Hydrologically Connected areas are placed under a state-imposed moratorium (since 2008) when the Department of Natural Resources preliminary declared the Lower Platte Basin 'fully appropriated'. The declaration was later reversed and the moratorium areas were opened back for limited irrigation development. In Restricted development areas offsets are required, "so if a landowner wishes to expand their water use at one location, then a similar amount of water use or acres must be retired within the same sub-area." Also, "Variance requests (with no offsets required) will be accepted for expanded irrigation if the field is within one mile of the border of the Restricted Development Area."[141]

[141] Lower Platte North NRD, http://www.lpnnrd.org/projects/water/gwma/irrigation_devareas.html (accessed 20th of January 2016).

Table 9. Rules for groundwater management in the Lower Platte North NRD

Condition	*Level 1*	*Level 2*	*Level 3*
Trigger Level	*None, but water conservation encouraged district-wide*	Unconfined Aquifer = 10% decline Confined Aquifer = 7% decline	Unconfined Aquifer = 15% decline Confined Aquifer = 10% decline
NRD will certify historically irrigated acres (a)	**Required**	**Required**	**Required**
Operators of irrigation, municipal, and industrial well systems attend education classes and be certified every 4 years	**Required**	**Required**	**Required**, including some domestic and livestock well owners
Well spacing requirements shall be observed (varying depending on aquifer subarea)	**Required**	**Required**	**Required**
Water well permits (Class 1, 2, 3, or 4 depends on annual water use or number of irrigated acres)	**Required** for all new and replacement high capacity wells	**Required** for all new and replacement high capacity wells	**Required** for all new and replacement high capacity wells and some low capacity wells
Establish well metering program	***Encouraged for all high-capacity wells***	**Required** for all high capacity wells	**Required** for all high capacity wells and some low capacity wells
Acre-inch allocations per crops planted, dependent on aquifer subarea.	***Encouraged***	**Required** or may be offset by reduction in number of irrigated acres	**Required** or may be offset by reduction in number of irrigated acres
Annual water use report made to LPNNRD by January 31st of the following year.	***Encouraged on existing wells,*** **required** on new and replacement high capacity wells	**Required** on existing high capacity wells and on new and replacement high capacity wells	**Required** on existing, new, and replacement high capacity wells and some low capacity wells
Best management practices used.	***Encouraged***	***Encouraged***	***Encouraged***

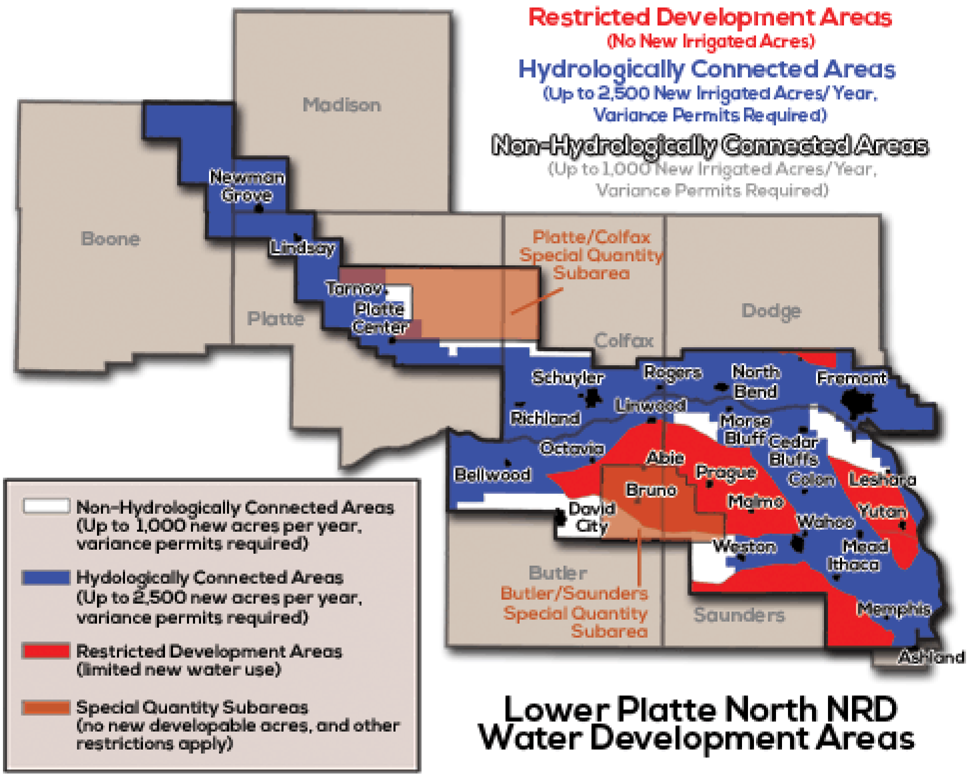
Note: (a) The certification process of historically irrigated acres verifies the number of acres irrigated by groundwater wells throughout the NRD and correct errors in existing records. Acres irrigated prior to 2004 in the Lower Platte will be certified at 95 percent. Those between 2004 and 2008 will be certified at 100 percent.
Source: Lower Platte North NRD.

There are also special Quantity Subareas defined by the NRD where "groundwater levels can be highly volatile and heavily influenced by drought and groundwater pumping." According to the NRD, special requirements apply in these subareas for:

- amounts to be determined for acre inch allocation of irrigation water
- no new or expanded irrigated acres
- all existing irrigated acres must be certified with the NRD by May 15, 2014
- beginning in 2015, flow meters required on all irrigation wells
- annual reporting of static water levels for all irrigation wells
- new domestic and livestock wells must be drilled to a depth that will avoid seasonal water declines caused by existing wells nearby

Restrictions on pumping during certain times of the day or the establishment of a system of rotation for pumping could also apply.

Figure 55. Types of water management areas in the Lower Platte North NRD



Source: Lower Platte North NRD.

1.7 Groundwater quality pollution and control in Nebraska

Increasing groundwater pollution in Nebraska is a concern as, since 2002, the percentage of groundwater samples exceeding the 10 mg/litre of maximum contaminant level for safe drinking water increased from 27 to 33 percent (around 88 percent of the state's population relies on groundwater for drinking water) (BGMAP 2014). Following Exner et al. 2010, 85 percent of Nebraska's population relies on groundwater for their potable water supply. The assessment of 5,800 wells between 1984 and 1989 found that 20 percent of wells exceeded 10 mg N/l MCL. Following their research, "more than half of the wells exceeding the MCL were located in intensively row-cropped areas characterized by fence-row to fence-row, irrigated, predominantly corn mono agriculture, well-drained soils, and a short distance(<15 m [<50 ft]) to groundwater" (Exner et al. 2010: 287).

An analysis of the long term contamination by nitrates in East Nebraska (Exner et al. 2014) indicated that the level of contaminations extends to 1.3 million hectares. The occurrence of contamination is dependent on agricultural practices and the hydrology of the area, soil drainage characteristics, vadose zone thickness, and type of irrigation method (ibid.). Highest concentrations of nitrates are found in areas with very sandy vadose zones and spray application of water by centre-pivots and the unsaturated zone varies from 15 to 30 metres thick. High nitrate concentrations occur at all depths (facilitated by a high concentration of high-capacity wells increasing vertical mixing) (ibid.). Within the span of 30 years, the area showing groundwater nitrate concentrations higher than 10 mg per litre nearly doubled during each of these three decades (ibid.). Contaminated areas show increasing irrigation intensity and in the decade 2004-2014 around 30 percent of the irrigated area "was underlain by nitrate-contaminated groundwater" (Exner et al. 2014: 4477). During 20 years of groundwater pollution management, only two reversals of an otherwise increasing trend over 120,500 hectares have occurred in the Central Platte valley (with a decline in concentrations of 0.14 and 0.20 mg per litre per year to concentration levels of 18.3 and 18.8 mg per litre respectively) (Exner et al. 2014).

In 1981, the Groundwater Management and Protection Act granted NRDs "authority to protect groundwater quality; however, nonpoint source contamination was not seriously addressed until sweeping revisions to the Act in 1986 authorized NRDs to form management areas, primarily to protect groundwater quality, and allowed NRDs to require implementation of best management practices and attendance at educational programs designed to protect water quality" (ibid.).

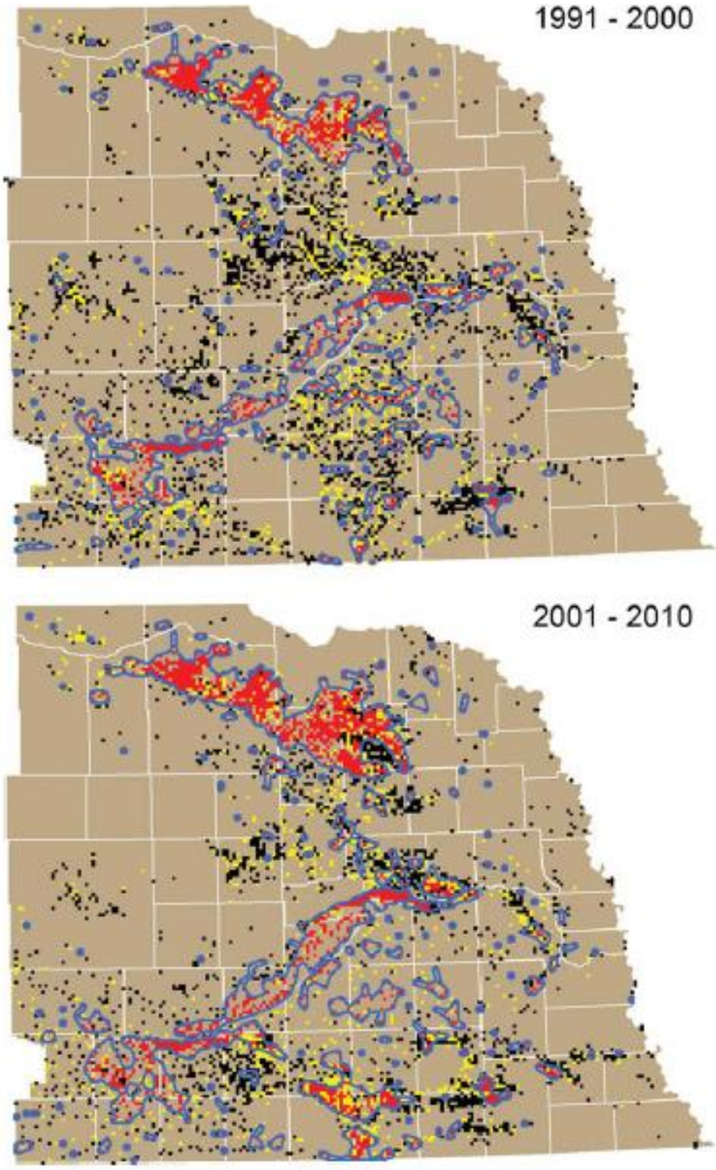
As seen above, NRDs can establish groundwater management areas (including measures to tackle pollution) after preparation of a groundwater management plan. Plans had to be revised by 1993 in order to reflect groundwater contamination from agricultural chemical use but the implementation of the plans remains an option for NRDs (Peterson et al. 1993). These management areas can be declared by more than one NRD. The Bazile Groundwater Management Area for instance, part of four NRDs in the northeast of Nebraska, was originally identified as an area of concern in the late 1980s as a result of nitrate contamination affecting municipal wells coming from fertilizer application and irrigation (BGMAP 2014). Assessments of nitrate levels indicated that 17 out of 21 townships showed an average concentration exceeding 10 mg per litre and more than 50 percent of wells showed an increase in nitrate levels from their first recorded measurement (ibid.).

In the Bazile Groundwater Management area, the strategies to treat contaminated water over the last 20 years have varied from using reverse osmosis to replacing wells (for a cost of more than USD 9 million). NRDs have to address non-point source pollution with incremental actions to mitigate pollution. Actions undertaken can range from immediate voluntary programs, to regulations with penalties, 5-year goals such as educating farmers and reducing average nitrate concentrations (by 3.2 mg/litre) to long term goals (20 years). The actions to be undertaken under the latest management plan in 2014 include amongst others: soil and irrigation sampling; irrigation scheduling and soil sensors; water meters; ban on nitrogen fertilizer (organic or inorganic); nutrient analysis of manure applied to soils; crop tissue analysis by farmers; fertigation for 90 percent of corn producers; nitrogen budgeting and accounting (ibid.).

For the Lower Loup NRD, its Groundwater Management Plan established the following goal in terms of groundwater quality. The main objective is to maintain the quality of groundwater within maximum contaminant levels as established by the Department of Environmental Quality and the Department of Health and Human Services of Nebraska (Lower Loup NRD 2015). The NRD also aims to establish a program for public information and education in order to reduce non-point source groundwater pollution. The NRD divided its territory into 28 groundwater quality sub-areas and three levels of control (referred as phases). Phase I is triggered with median nitrate nitrogen levels of 0 to 6.5 mg/l (milligrams per litre). Phase II triggered set with median nitrate nitrogen levels of 6.6 to 8.5 mg/l over a continuous 4 year period. Phase III is triggered with median nitrate nitrogen levels of over 8.6 mg/l over a continuous 4 year period.

Groundwater contamination can also be dealt with via the special groundwater quality protection program, designated by the Nebraska Department of Environmental Control without permission from NRDs. Upon designations, NRDs have to regulate the application of agricultural chemicals under Departmental supervision (Peterson et al. 1993). The Nebraska Department of Environment Quality delineates 'wellhead protection areas' (WHPA) for all public water supply systems in the state, generally corresponding "to the predicted 20-year time-of-travel zone for the supply wells […]. In other words, the WHPAs represent the area from which ground water could be expected to be extracted during 20 years of normal water use for those public water supplies" (LPSNRD 2014: 3). These wellhead protection areas were originally designated in 1965 when it was ruled that well spacing requirements among irrigation, industrial, and public water wells would be 1,000 feet (originally used for only wells supplying cities but in 1980 it was extended to any well used by a city, village, rural water district, NRD, municipal corporation, utility) (Aiken 1980).

Figure 56. Decadal emergence of nitrate pollution in groundwater in Eastern and central Nebraska



Note: Black cells depict average concentrations in irrigation wells < 5 mg N/l; yellow cells 5 to <10 mg N/l; red cells ≥ 10 mg N/l.
Source: Exner et al. 2014.

1.8 The state vs. local communities in groundwater management

1.8.1 Problems of institutional fit and hierarchies

Stephenson (1996) has looked at the responses from local NRDs to groundwater over-abstraction. These seem more varied than expected, de-mystifying according to him the idea that all local resource districts behave like 'closed clubs of irrigations' only aiming to preserve the status quo. However, authors such as Longo and Miewald (1989: 753) consider Nebraska's groundwater management as an example of how the resource is managed "tangentially by authoritative policy statements by the legislature" and the fact that the awareness of management limitations from policymakers has not been "associated with a desire on the part of any major actors to relinquish their 'fair share' of water." Longo and Miewald (1989) considered NRDs as a "major repository of legislative power in the field of water policy" where the principle of local democracy rather than competence in technical matters has been guiding the devolution and respect of local powers. Furthermore, according to Peterson et al. (1993: 46), NRDs are subject to intense pressure from local entitlement-holders, which makes it difficult for them "to guide the redefinition and reassignment of water rights without support from institutions established at the state or federal levels."

The maintenance of a split hierarchy between state bodies and NRDs has developed into "a nested hierarchy with a strong emphasis on local control […] part of a polycentric system, which, in addition to the state, includes irrigation districts, counties, and municipalities. Individual NRDs may have jurisdiction in several different counties, one NRD has jurisdiction in 13 different counties, and many counties have to work with several different NRDs. These overlaps can be a source of irritation for county officials. Nevertheless to deal with issues of mutual concern, some NRDs have been able to work with these other jurisdictions to establish bridging organizations through inter-local agreements" (Bleed and Hoffman Babbitt 2015: 83).

The localization of groundwater management at the NRD level has caused that different NRDs have different management plans and different trigger levels which can cause problems. NRDs can have different levels of groundwater volumes allowed to be pumped out, depending on the need to supplement rainfall with groundwater pumping from the aquifers (Bleed and Hoffman Babbitt 2015). Some NRDs will have highs of an average of 65 inches pumped over five years and others will have 21 inches over three years (ibid.) (Table 8).

NRDs have also different management trigger levels. In 2015 it was reported that declining groundwater levels in the Tri-Basin NRD triggered Phase 2 of the district's Groundwater Management Plan, requiring flow meters for all wells installed within 3 years and pumping levels would have to be reported annually. On the other side of the county line however, groundwater levels are also declining but, as it is part of another NRD, the Little Blue NRD, it follows different trigger systems. As a result, following an article in the Hastings Tribune, "May Township farmers, who have been unable to develop new acres for irrigation since 2005 [31,641 acres], believe continuing irrigation development in the Little Blue district is sucking water from beneath their fields and pulling it downgradient. They want that to stop, and they have told their Tri-Basin representatives they expect the district to protect their interests" (Hastings Tribune 2015). As a response to this situation, the board of the Tri-Basin NRD voted to postpone the implementation of Phase 2 until at least January 2016.

Even if this situation is created by the NRDs local natural conditions, some NRDs have been able to cooperate to tackle basin wide solutions and new legislative action in 2014 also sought to close this gap with LB 1098, requesting basin-wide planning in areas where at least 85 percent of three or more NRDs are fully determined to be fully appropriated (Bleed and Hoffman Babbitt 2015). Additionally, even if there are no centralized basin-wide authorities with jurisdiction over the basin, the Nebraska Association of Resources Districts has focused on coordinating the activities of the NRDs across political boundaries (ibid.).

This polycentric system however, according to these authors, has avoided problems of legitimacy "and has implemented management actions in a more democratic fashion than would have been likely with a central top-down basin authority" (Bleed and Hoffman Babbit 2015: 88). A former senior attorney for rivers and deltas from the Environmental Defence Fund was quoted by the NARD (Nebraska Association of Resources Districts) saying that "[l]ocal interests may be more aggressive than state policy makers in protecting their resources," thus assuming that this system was "preferable to other states" (NARD 2015: 1).

The authority granted to NRDs has been however discretionary and not mandatory as they were not compelled "to do anything when faced with crucial groundwater quality problems, especially if those issues might contain some serious political risks" (Longo and Miewald 1989: 758). Control areas could only be declared following the initiative of the users themselves leaving any other state actors or powers outside. As Peterson et al. (1993: 46) wrote, if the local NRD decides to ignore its problems of groundwater depletion, "the state has no authority to undertake the regulatory process on its own motion."

Following Cash (2003 in Sophocleous 2010: 570) however, the idea behind the creation of NRDs was to match institutional boundaries "to boundaries of consequence for resources, avoiding problems of poor institutional fit". They were also created with sufficient size in order "to capture efficiencies of scale and minimize transboundary problems" and can merge and split as perceptions of what constitutes effective and efficient management can change (this has only happened once in 1989 when two NRDs merged) (Sophocleous 2010). However, even though the original idea behind the creation of NRDs was to adopt a river basin regulation structure, the authority to manage large basins was split amongst several NRDs to ensure local control and given their local nature, NRDs will tend to focus on internal issues rather than basin-level concerns (Bleed and Hoffman Babbitt 2015). This structure therefore can destabilize the river basin approach even though NRDs have been able to work together on some issues (compliance with the Endangered Species Act for example) (ibid.). NRDs' activities are coordinated by the Nebraska Association of Resources Districts, focusing on working with NRDs across political boundaries (ibid.).

Local perceptions on NRDs gathered and studied by Hoffman (2013) in the Platte River Basin show that local control via NRDs is supported by most users throughout the basin. These perceptions, expressed by one farmer, emphasized that locally tailored management districts "can better address the diverse water resource challenges associated with the 'completely different climate, as well as different geology and hydrology' that exists from one end of the state to the other" (Hoffman 2013: 35). Perceptions studied by the author also reflect how local management can foster "the development of 'innovative solutions' that would not be possible if management was imposed from the state. Local expertise and first-hand knowledge of the resource not only allows management strategies to be customized to the issues at hand but can more quickly and effectively address problems if they arise. […] 'the NRD is close to the constituents it serves'" (ibid.). Following her research, elements of centralizing versus local powers appear, as quotations indicate how, if something is not done locally, "it will be done for us on a state-wide basis" (ibid.).[142]

1.8.2 NRDs, local management, and the implementation of rules

For Kepfield (1993: 241), the "apparent abundance of groundwater is crucial in explaining the course of Nebraska groundwater law". This is a point also touched upon by Aiken (1980: 919) when he wrote that Nebraska's groundwater law "is not so completely developed because the relative abundance of ground water has postponed many of the user conflicts that are at the basis of legislative or judicial precedents". With the rapid development of irrigation however, it is more difficult to ignore conflicts between uses and "forcing consideration of ground water policy issues previously ignored" (ibid.).

Also, changing power relations between rural communities and growing urban areas is shifting the balance and could allow for further modifications in the existing structure of groundwater property rights in Nebraska (Mossman 1996). The Nebraska legislature established a groundwater preference scheme stating the preferences for usage: first comes domestic; second, agriculture; and third, industry (ibid.). Conflicts under this system could easily arise as no authority grants the right to use groundwater outside of designated groundwater control areas but only one dispute that we know of had been registered by 1993 in the Nebraska Supreme Court (ibid.). So far, 12 NRDs have implemented rules to prevent over-abstraction of groundwater (Bleed and Hoffman Babbitt 2015).

This localization of groundwater management through NRDs has apparently not led to a 'judicialization' of the management of the resource (whereby decisions and conflicts are settled in courts) as it would seem the case following the groundwater laws of the state (Kepfield 1993; Longo and Miewald 1989). NRDs are allowed to come up with their own rules to control groundwater abstraction. Longo and Miewald (1989) proved that the decentralization did not lead to many water cases in the courts' agendas and it would seem that conflict resolution was taking place in other arenas (mainly the NRDs themselves and the DWR) as there is a tendency to defer to the local administrative units decisions about groundwater (ibid.). Legislation left farmers to rely on informal arrangements and lawsuits to resolve irrigation conflicts (Kepfield 1993).

Initiatives by three NRDs to establish water-allocation rules had been met by resistance from local entitlement holders and the ruling from a county court had to be obtained in 1993 in one case, in order to force a farmer who had exceeded his water allocation to cease irrigating (Peterson et al. 1993). Other cases having reached the Supreme Court of Nebraska found the literature included a case reviewed by the Supreme Court in 2001 where two plaintiffs applied to the Upper Republican NRD in 1998 for a variance of groundwater allocation which was refused.[143] Another reason could be that a Nebraska

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[142] The movement towards integrated management plans, following Hoffman's (2013) research, seems to have developed a higher degree of trust amongst institutions and users as it has increased the ability of users to influence rules and facilitated interaction between state and local water management agencies. It also incorporated flexibility into management systems and foster shared knowledge.

[143] Supreme Court of Nebraska, 2002, Official Report of Cases, decided between January 12, 2001 and June 21, 2001, Volume CCLXI, State of Nebraska, Lincoln, https://supremecourt.nebraska.gov/sites/supremecourt.ne.gov/files/nebraska-reports/261_Nebraska_Reports_pdf-1ab.pdf (Accessed 4th May 2015).

Supreme Court ruling in 2008 appeared to limit the range of actors with the power to challenge NRD decisions (especially when it comes to conflicts between surface and groundwater users).[144] As reviewed by Hamm (2014), NRDs challenges over water regulations have been defeated in two out of three cases in the Supreme Court. It would seem therefore that the courts seem "notably deferential to state natural resource authorities" against local institutions and agencies (Hamm 2014: 20).

Sophocleous (2010) however refers to the fact that NRDs' rules would in some cases remain ineffective were it not for the courts. One of the reasons could be that, following a Nebraska Supreme Court ruling, according to the Groundwater Management and Protection Act, one of the goals of a management plan is not to adjudicate a specific dispute through trial proceedings, "but to develop controls to address the area’s water problems by employing the traditional tools of rulemaking, i.e., studies and public meetings."[145] The view of NRDs in tension with a centralizing state in Nebraska is also put forward by Longo and Miewald (1989: 762) when they wrote that NRDs have been adjusting to new political realities and pressures, seeing "the political forces in the state, and not the courts, as the greatest threat to their best interests and to their central role in water policymaking".

Bleed and Hoffman Babbitt (2015) also report on a history of mistrust between the state Department of Natural Resources and the NRDs and also between surface and groundwater users. This is due to inequity issues and water allocation between surface users and groundwater users. This conflict has been felt mostly in the Republican Basin where surface water users have been receiving substantially less water than groundwater irrigators for years (ibid.). In 2013, surface water irrigators were told that their rights to divert or store water had to be upheld so that Nebraska could comply with the Republican River Compact whilst, in the same districts groundwater users were able to use from 10.5 inches to 13 inches per acre or in some cases more (ibid.).

[144] The Supreme Court ruled in this case that a surface water irrigation district did not have standing to appeal a 2008 decision by a NRD to lower groundwater allocation from 14 to 12 inches per acre (as one of its measures to control water-use within its boundaries) (Kelly 2010).

[145] Supreme Court of Nebraska, 2007, Official Report of Cases, decided between December 23, 2004 and June 23, 2005, Volume CCLXIX, State of Nebraska, Lincoln, 199.

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Part 3. Groundwater governance in California, Oregon, and Florida

1 Groundwater in California

1.1 Aquifers in California

Although groundwater supplies about 30 percent of urban and agricultural use across California, some areas are more than 80 percent dependent on this resource for their agricultural and urban demand (i.e. the Central Coast Basin). In California, domestic uses represent 82 percent of groundwater demand, and agriculture 14 percent. More than 70 percent of groundwater in California is abstracted in the Central Valley (Sacramento, San Joaquin and Tulare basins), which depends at 30 to 40 percent on groundwater, and the urban area of the South Coast (Los Angeles, San Diego), dependent at 23 percent (Osugi et al. 2003).

The South Coast (Figure 57) covers an area of 10,600 square miles, with 56 delineated groundwater basins. The Los Angeles subregion overlies 21 groundwater basins which make up about 40 percent of the total area of the subregion. This area has been using groundwater for over 100 years and the Raymond Groundwater Basin in the Los Angeles County was the first adjudicated basin in the State (ibid.).

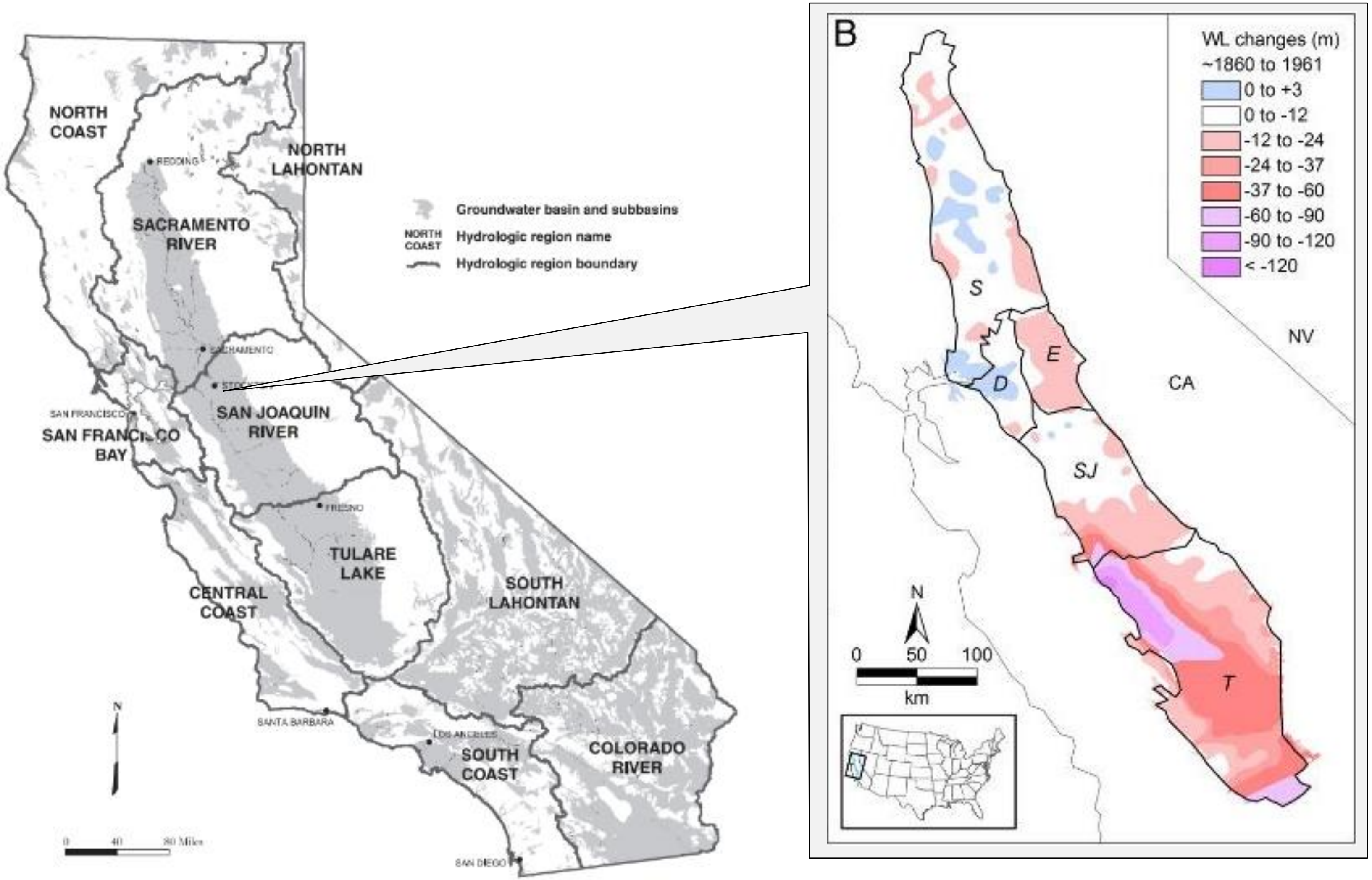
The Central Valley of California covers 52,000 Km2 and agricultural production in the area has been valued at 21 billion USD (Scanlon et al. 2012). Groundwater depletion here has been estimated at 14 percent of groundwater in storage before irrigation (140 Km3). This depletion according to Scanlon et al. (2012) is highly episodic, restricted primarily to drought events, as many farms are equipped to use both surface and groundwater. These droughts are also associated with recharge reductions by up to 60 percent. Depletion is greater in the south of the basin, with up to 120-meter variation in water levels in the Tulare Basin (Figure 57). Large-scale surface water transfers to the south, since the 1950s and 1960s, helped recover aquifer levels in some areas in the south by up to 90 meters from reduced pumping and increased recharge (ibid.). Irrigation well depth commonly varies between 30 and 240 meters in the San Joaquin valley, between 100 and 200 meters in the Tulare basin, and can exceed 300 meters in the Sacramento Basin (Osuji et al. 2003).

1.2 Groundwater regulation in California

The case of California is unique amongst the western states of the United States as it does not have a state-wide regulated groundwater management system and has instead a largely localized groundwater management system, whereby local agencies and users collectively organize how best to manage groundwater (Donohew 2012). Additionally, unlike other states in the USA, instead of adopting a specific legal doctrine for groundwater rights, California adopted a dual system of groundwater rights.

When it joined the Union in 1850, California adopted the English common law doctrine of absolute groundwater ownership which stated that landowners were entitled to enjoy absolute ownership of groundwater underlying their properties. In 1903 however, the California Supreme Court established in its *Katz vs. Walkinshaw* ruling that the absolute ownership doctrine of rights was inappropriate for the state's natural resources and adopted the doctrine of correlative rights (Donohew 2012).

Figure 57. Groundwater basins in California and simulated groundwater level changes in the Central Valley



Note: Simulated groundwater level changes in meters from predevelopment (~1860 to 1961) in California's Central Valley. T= Tulare Lake; SJ= San Joaquin River; D=Delta Side; E=East side; S=Sacramento Basin. Source: Osuji et al. 2003 and Scanlon et al. 2012.

According to the correlative rights doctrine, each overlying landowner was entitled to make reasonable beneficial use with a priority equal to all other users, not according to seniority (Donohew 2012).[146] The amount of groundwater allocated is dependent on the surface area owned and landowners can see their allocated portion diminished if the total amount available decreases (e.g. in the case of a drought) by a court order (Hutchins 1957). Also according to this doctrine, when landowners do not use all of their correlative rights and a groundwater basin has more water available than it needs, surplus groundwater can be distributed if a district wants it, through a prior appropriation system to users outside the groundwater basin (so-called off-tract use) (Harter 2001). If the groundwater overlying use increases however (e.g. due to an increase in agricultural activities) the most junior offsite groundwater user will be curtailed first (ibid.).[147]

Therefore, this duality of rights is subject to the hierarchy of correlative rights over appropriative rights (i.e. water pumped for use on the overlying land has priority over water pumped for use off the land). This dual system of rights would benefit ultimately the overlying user of the right over the appropriator taking the available surplus from a groundwater basin (the right of an appropriator is only that of the surplus of groundwater from the overlying user) (Hutchins 1957). This system also benefits those land owners with large expanses of land to the detriment of those with a large demand but without large land areas (e.g. cities).

Moreover, legal codification of groundwater in the California Water Code relates to an antiquated misnomer of subterranean streams bearing no connection to hydrogeology (Gerlak et al. 2013). The state of California categorizes groundwater as either a "subterranean stream flowing through a known and definite channel" or "percolating groundwater" (Gerlak et al. 2013: 2). Groundwater considered as a "subterranean stream" is subject to the same water rights system as surface water. A subterranean stream is defined as: 1) a subsurface channel must be present; 2) the channel must have relatively impermeable bed and banks; 3) the course of the channel must be known or capable of being determined by reasonable inference; 4) groundwater must be flowing in the channel. For percolating groundwater, the state does not have a statewide permit system (Gerlak et al. 2013).

In California there is a generalized lack of data on groundwater abstractions, as many basins have no record of how much water is withdrawn, where it was pumped from, and how much water remains in the aquifers (Choy et al. 2014). Well log[148] data is publicly available in all western states except California, where the law actually prohibits public access to well logs compiled by drilling companies (even if they have to submit them to the State's Department of Water Resources) (ibid.). Data about wells contained in the well log can only be accessed by

[146] Overlying rights appeared and were first applied following the riparian principle that water use rights are recognized to those owning land adjacent to surface water. Overlying rights to use groundwater, therefore, went to those land owners overlying groundwater reserves (Donohew 2012).

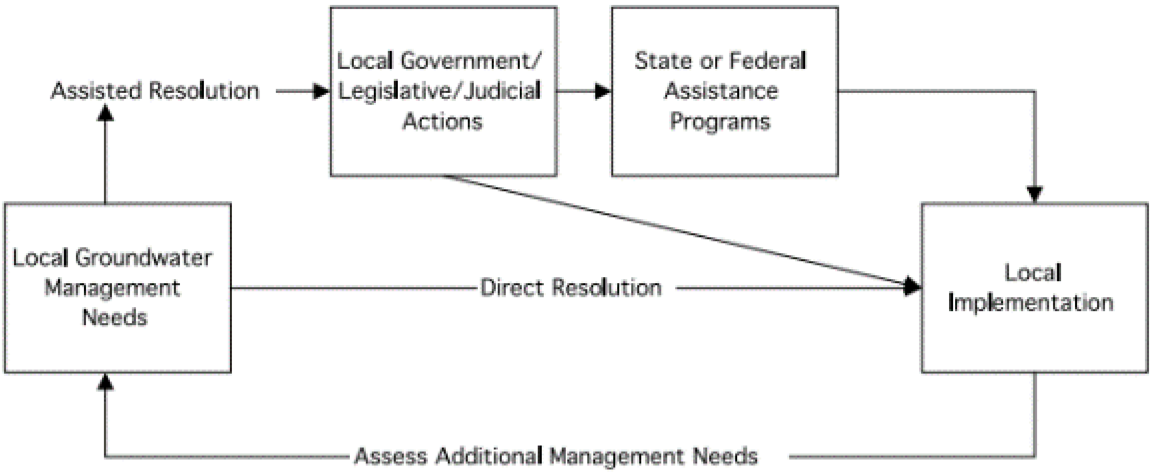
[147] This poses a disruptive potential problem for the future water supply of users relying on groundwater from a neighboring or distant groundwater basin to which overlying users have prior appropriative rights. As Harter (2001: 5) wrote, if the off-tract user is a large water provider for municipalities, they are also "subject to prior appropriation and junior to correlative right holders, even if those water deliveries are to overlying land owners". An important example of this conflict between correlative rights and prior appropriation rights of users is the conflict that developed in the 1930s and 1940s in the Raymond Basin in Southern California. It was determined that the basin had been critically overdrawn and overlying users (including ranches, golf clubs, and public utilities) determined by consensus alongside 'off-tract' users such as larger public utilities serving water to areas outside the basin, that groundwater pumping had to be reduced equitably. In such case, both the overlying users and off-tract users decided not to apply the prior appropriation doctrine which would have required that all junior off-tract users discontinued pumping groundwater (Harter 2001).

[148] Well drilling logs include information on location, depth, and subsurface geology, collected by the drilling company when a well is drilled (Choy et al. 2014).

government agencies with the well owner's consent. According to Choy et al. (2014), this lack of data, is due to a 'chronic' underfunding of state-wide groundwater monitoring programs (the last, in 2009, the California Statewide Groundwater Elevation Monitoring, tracking seasonal and long-term trends in groundwater elevation). As Grantham and Viers (2014) purport, the chronic underfunding of California's water regulatory agencies is a major constraint to modernizing the state's water rights system. This lack of funding contributes to "decades-long backlogs in processing water rights applications" and reflects, in part, "political opposition to action by those who benefit from lax enforcement" (Grantham and Viers 2014: 8).[149]

Although the regulation of groundwater by the State of California has been considered on several occasions, the Legislature has repeatedly held that groundwater management remains a local responsibility (Osuji et al. 2003). Under the existing Law in California, there are three main ways to manage groundwater in California: via local water districts, local ordinances, and court adjudications (Figure 59) (Donohew 2012). Local groundwater management needs can either be solved locally or, when assistance is required, they seek government or judicial actions (court adjudications) which can also be supported by state or federal programs (Figure 58 and Table 10).

Figure 58. Process of addressing groundwater management needs in California



Source: Osuji et al. 2003.

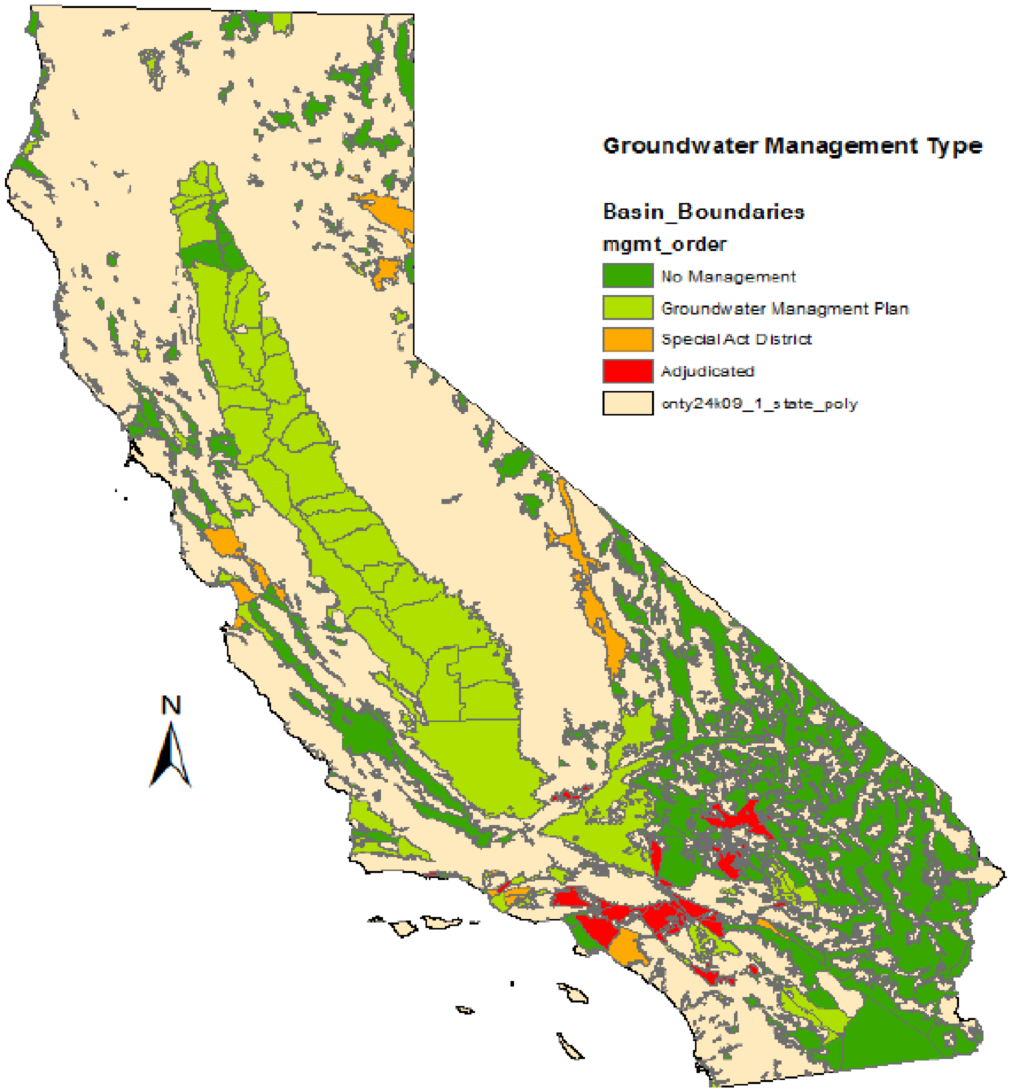
[149] Moreover, the lack of data by California's water agencies during the 2014 drought episode has led to emergency curtailments of all water uses in specific catchments, a measure that would not have been necessary had there been accurate information. This would have been used to target specific water users "and develop cooperative strategies to reduce water diversion impacts on environmental flows" (Grantham and Viers 2014: 8).

Table 10. Groundwater regulation options in California

Type		Number	Powers	Process
Local agencies	Local agencies	462	Varies – collect fees for services, levy extraction fees	Majority vote for proposed boundaries and service – tailored to citizen demands
	Special Act Districts	17	Limit export, levy fees, limit extraction in over-abstracted basins	Enacted by legislature after local consensus established
Ordinances		30	Limit export of groundwater, monitoring of wells, construction well standards, well permitting, well spacing	Enacted by local councils
Adjudication		22	Varies but typically regulates extraction, assesses fees and allows trading	Begins with law suit demonstrating over-abstraction. Parties reach negotiated agreement or court determines allocation

Source: Adapted from Donohew 2012.

Figure 59. Groundwater management types in California



Source: Donohew 2012.

1.2.1 Local agencies

Groundwater management needs are first identified at the local water agency level and may be resolved at the local level. Local Agencies can require existing government bodies and authority to proactively monitor and manage groundwater resource issues (e.g. Irrigation districts, County Water Districts) since the passage of the Assembly Bill 3030 in 1992 (Osuji et al. 2003). There are more than 20 different types of Local Agencies authorized by statute to provide water for various beneficial uses, with some also having statutory authority to institute some form of groundwater management. These can be County water districts and authorities, irrigation districts, municipal water districts, recreational and park districts (Table 11). As Donohew (2012) explains, the power of local agencies is derived from state law allowing for the creation of special districts to meet local needs. These districts are formed by applying to the Local Agency Formation Commission who studies and reviews the proposal before holding a public hearing. A simple majority (50 percent) is required for the approval of the district amongst the members of the commission (Donohew 2012).[150]

California's Assembly Bill 3030 was approved in 1992 and laid out the general framework and additional authorities for local agencies to develop and implement groundwater management plans, encouraging local-level groundwater management in basins (Gerlak et al. 2013). This legislation also permitted a local agency, which can include a special district or a group of agencies, to adopt and implement a groundwater management plan. Groundwater management programs have usually been developed on an ad hoc basis in response to local initiative through local agencies, adjudication and specially formed districts (Osuji et al. 2003).

All agencies formed since 1980 have the authority to limit export and even control in-basin extraction upon evidence of overdraft, or threat of overdraft. They can also levy fees for groundwater management activities and for water supply replenishment. Agencies formed before 1980 do not have authority to limit extraction from a basin, although users are generally required to report abstractions to the agency. The agency can also levy fees for groundwater replenishment. According to Osuji et al. (2003), some of these agencies have used a system of reporting extractions and tiered pump fee structure to discourage excessive groundwater extraction in the basin (but without limit on extraction) (Harter 2001). In terms of control of groundwater, local agencies "are required to monitor the elevation of their groundwater basins, though there is no requirement for monitoring or tracking groundwater pumping" (Little Hoover Commission 2010: vii).

Local agencies have historically resisted groundwater metering (Nelson 2011). Recently, although there is great variation in the motivations and practice of metering, many special districts and some general districts in California apply mandatory or voluntary groundwater metering (ibid.). Management problems related to monitoring of production wells and others can lead to data gaps and infrequent measurements. As Nelson (2011) describes, data can be collected but not systematically compiled into a useful format. Additionally, drilling information for wells may not be known, so it is not clear which aquifers layers are actually being monitored.

In 1991 Assembly Bill 255 was enacted authorizing local agencies overlying basins experiencing critical overdraft, to establish programs for groundwater management. The Californian Water Code provided these agencies with the powers of a water replenishment district to raise revenue for facilities to manage the basin for the purposes of abstraction, recharge, conveyance, and water quality. Seven local agencies adopted plans under this code.

In 1992, Assembly Bill 3030 increased even more the number of local agencies authorized to develop a groundwater management plan and set forth a common framework for groundwater management by local agencies. Agency participation through Assembly Bill 3030 is however voluntary, and agencies' plan do not have to be filed with California's Department of Water

[150] The most common type of Local Agency are County Service Areas (CSA) (Table 11). These County Service Areas are regulated by the CSA Law and allow small communities in unincorporated areas to provide expanded service levels in areas where residents are willing to pay for the extra service. The law allows residents or county supervisors to initiate the formation of a CSA, authorizing it to provide a wide variety of services including extended police protection, fire protection, park and recreation facilities, and garbage collection if they are not already performed on a countywide basis. These CSA are initiated by a petition of registered voters or by adoption of a resolution at the county level. The property owner within a CSA will pay taxes for the services provided, billed as line items on the county property tax bill (California Property Tax Information, http://www.countyofplumas.com/DocumentCenter/Home/View/3939, Accessed 10th August 2014).

Resources, limiting their reach and effectiveness, according to Langridge (2012). Twelve technical components are identified in the Code as pertaining to these groundwater management plans (e.g. saline water intrusion, wellhead protection, groundwater contamination, facilitation of conjunctive use operations). The plan can be developed only after public hearing, and rules and regulations must be adopted to implement the plan. The management authority to determine and collect fees and establish these assessments is subject to local elections obtaining a majority of votes in favor of the proposal. In spite of the fact that more than 200 agencies have adopted a groundwater management plan under Assembly Bill 3030, none of these agencies was known to have exercised such authority during the 2000s (Harter 2001). Senate Bill X7-6 in 2009 granted the Department of Water Resources the responsibility of setting up "a priority schedule and providing local assistance" for local agencies in case of drought (Little Hoover Commission 2010: 25). According to the Bill, if local agencies fail to comply, "the department is responsible for establishing a program for them" (ibid).

In 2000, Proposition 13 provided 200 million USD for grants for feasibility studies, groundwater storage, and an additional 30 million USD for grants for groundwater recharge projects (Hanak and Stryjewski 2012). In 2002, the California Legislature approved Senate Bill 1938, establishing a system of carrots and sticks as it required local agencies to develop and implement Groundwater Management Plans with specific components in order to be eligible for state funding (Osuji et al. 2003). These funds, provided by the Department of Water Resources, were to be allocated to the construction of groundwater projects or groundwater quality projects and had to include:

- Basin management objectives;
- Components relating to the monitoring and management of groundwater levels, quality, land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping;
- A plan by the managing entity to cooperate with other entities and actors whose service area overlies the groundwater basin;
- A map establishing the boundaries of the groundwater basin and establish the boundaries of other local agencies overlying the basin.

Table 11. Local agencies with authority to deliver water for beneficial uses

Local agency	Authority	Number of agencies[a]
Community Services District	Gov. Code § 61000 et seq.	313
County Sanitation District	Health and Safety Code § 4700 et seq.	91
County Service Area	Gov. Code § 25210.1 et seq.	897
County Water Authority	Water Code App. 45.	30
County Water District	Water Code § 30000 et seq.	174
County Waterworks District	Water Code § 55000 et seq.	34
Flood Control and Water Conservation District	Water Code App. 38.	39
Irrigation District	Water Code § 20500 et seq.	97
Metropolitan Water District	Water Code App 109.	1
Municipal Utility District	Pub. Util. Code § 11501 et seq.	5
Municipal Water District	Water Code § 71000 et seq.	40
Public Utility District	Pub. Util. Code § 15501 et seq.	54
Reclamation District	Water Code § 50000 et seq.	152
Recreation and Park District	Pub. Resources Code § 5780 et seq.	110
Resort Improvement District	Pub. Resources Code § 13000 et seq.	-
Resource Conservation District	Pub. Resources Code § 9001 et seq.	99
Water Conservation District	Water Code App. 34; Wat. Code § 74000 et seq.	13
Water District	Water Code § 34000 et seq.	141
Water Replenishment District	Water Code § 60000 et seq.	1
Water Storage District	Water Code § 39000 et seq.	8

a. From State Controller's Office Special Districts Annual Report, 49th Edition.

Source: Osuji et al. 2003.

Table 12. Special act districts with groundwater management authority in California

District or agency	Water Code citation[a]	Year agency established in Code[b]
Desert Water Agency	App. 100	1961
Fox Canyon Groundwater Management Agency	App. 121.	1982
Honey Lake Groundwater Management District	App. 129.	1989
Long Valley Groundwater Management District	App. 119.	1980
Mendocino City Community Services District	Section 10700 et seq.	1987
Mono County Tri-Valley Groundwater Management District	App. 128.	1989
Monterey Peninsula Water Management District	App. 118.	1977
Ojai Groundwater Management Agency	App. 131.	1991
Orange County Water District	App. 40.	1933
Pajaro Valley Water Management Agency	App. 124.	1984
Santa Clara Valley Water District	App. 60.	1951
Sierra Valley Groundwater Management District	App. 119.	1980
Willow Creek Groundwater Management Agency	App. 135.	1993

a. From West's Annotated California Codes (1999 update)
b. This represents the year the agency was established in the Water Code. Specific authorities, such as those for groundwater management activities, may have been granted through later amendments.

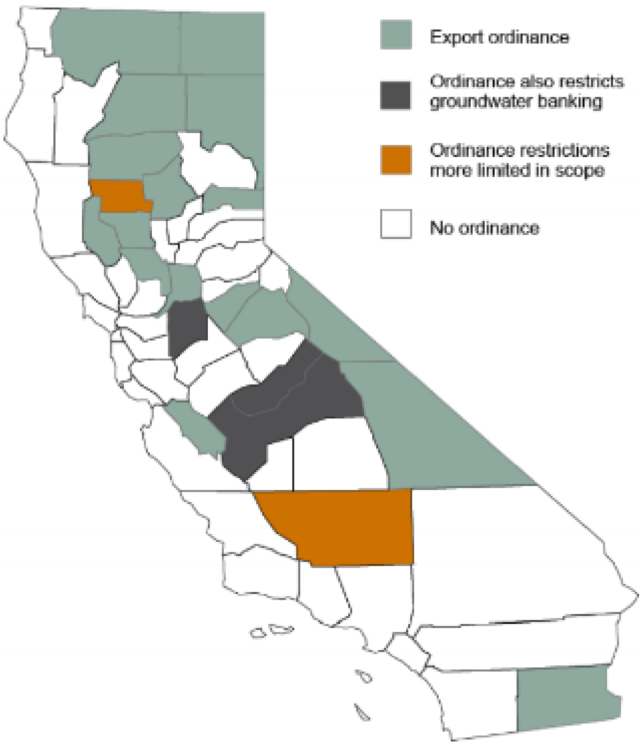
Soure: Osuji et al. 2003.

1.2.2 Groundwater ordinances

If management needs cannot be resolved locally, then additional actions such as the enactment of ordinances by local governments can be used to resolve the issues. In California, municipalities can invoke the right to exercise police powers to protect the public welfare in areas not regulated by the state. Since groundwater falls outside the jurisdiction of the state, these municipalities can invoke this prerogative and implement such ordinances in order to better coordinate water supply management and land development (Blacet et al. 2011; Donohew 2012; Hanak 2003). The possibility for counties and also municipalities to adopt groundwater ordinances was upheld by the California Supreme Court in 1995 when it declined to review a lower court decision ruling that state law is not concerned with groundwater and that it does not prevent cities and counties from adopting ordinances to manage groundwater. Up until 2013, 30 counties had adopted groundwater ordinances.

Groundwater management plans prepared under the Assembly Bill 3030 in 1992 brought unprecedented numbers of local water agencies into the groundwater management area. As a result, 24 out of the 30 groundwater ordinances have been enacted since 1990. As Osuji et al. (2003) reported, most counties have adopted groundwater ordinances in order to regulate groundwater exports. Additionally, shortly afterwards Tehama County won an appeal in 1994 upholding its authority to regulate groundwater (Hanak 2003). At the level of the state, 22 out of California's 58 counties have enacted groundwater ordinances that restrict the export of groundwater (Figure 60) (ibid.). These ordinances require that project proponents prove that the export project will not deplete groundwater, cause quality degradation, or result in land subsidence. This has become the main objective of these ordinances, thus limiting a potentially more comprehensive scope for a larger management program (Osuji et al. 2003).

Figure 60. Local ordinances regulating groundwater exports in California



Source: Hanak and Stryjewski 2012.

1.2.3 Adjudicated groundwater basins

Adjudicated Basins are managed according to modalities established by court decree, typically where overlying stakeholders cannot come to an agreement over the management of the resource, or about how much water can be abstracted. Of the 515 basins in California only 22 have been adjudicated since the first in 1944. This is due to the fact that it is an expensive process as all groundwater users in a basin have to be identified and historical data on groundwater pumping needs to be collected (Donohew 2012). Courts rule by adjudication, by studying the available data to arrive at a distribution of groundwater available per year, usually based on the California Law of overlying use and appropriation (Osuji et al. 2003). All groundwater extraction within these groundwater basins is adjudicated and specified in terms of amounts and users. In situation of over-abstraction, users owning adjudicated groundwater rights will see a reduction in the allowed pumping rate (Donohew 2012).

Due to the fact that these proceedings can be extremely long and costly (the longest adjudication took 24 years), many of these cases are resolved with a court-approved negotiated settlement. These rulings guarantee each party a proportionate share of the groundwater. These settlements would also have to negotiate overall abstraction levels by establishing a court-determined safe-yield for the basin, how the abstraction is allocated amongst users, and a cost sharing rule for monitoring, enforcing and replenishing groundwater (Donohew 2012). This results in a reduction or a freeze in the amount of groundwater to be extracted following the court ruling. As Osuji et al. (2003) wrote, this resulted in local agencies often importing surface water to increase supply (See Los Angeles Case). The courts also can appoint a 'watermaster' to oversee the court judgment.

Groundwater users may seek to limit groundwater extractions in over-abstracted basins by using the courts to determine the appropriate management and regulation rules.[151] Although the State of California encourages coordinated, basin wide management, the role of the state remains limited to providing technical and financial assistance to local agencies for their management efforts (such as through the Local Groundwater Assistance grant program) (Osuji et al. 2003).

1.3 California's groundwater banking[152]

Groundwater banking in California is a practice that involves the storage of surface water in aquifers during wet years in order to be used during dry years by the entity that stored the water (Christian-Smith 2013). This technique can augment the volume of water stored in aquifers (normally depleted due to irrigation in the past) and available for lease or sale during dry spells. This trading can happen between different management entities such as urban and agricultural water districts and other local entities, and also between farmers and other users within the same district.

Groundwater is available to be sold to private individuals overlying an aquifer, and municipalities that have issued a claim to use groundwater as appropriators. The ability to transfer groundwater between users of local agencies depends on the existence of local

[151] "Judges typically require a "physical solution" to common pool problems, which go beyond determining groundwater rights. The physical solution to a groundwater basin seeks to mitigate common-pool losses and maximize the beneficial uses of the groundwater basin. This may include creative agreements to artificially recharge a basin, procure supplemental water, improve water quality, and prevent seawater intrusion" (Donohew 2012: 32).
[152] Except when stated, section based on Hanak (2003) and Hanak and Stryjewski (2012).

ordinances which can limit groundwater exports in order to prevent harm to local users or avoid damage to local economies. Due to the interconnectedness of surface and groundwater, the California Department of Water Resources developed a set of guidelines in 2012 as part of a draft White Paper on groundwater transfers in the Sacramento Valley, restricting the location of wells that can be used for transfers and setting up pumping ratios taking into account the loss of surface water incurred due to pumping.

Groundwater banking benefits from normal and wet years to replenish local aquifers. When groundwater is needed within the district or for off-site uses, conveyance facilities can be augmented as well as pumping facilities, locally or at a larger scale. The transfer and exchange of groundwater (and for that matter of surface water) is enabled by California's extensive water infrastructure (Figure 61).

The approval of these groundwater transfers also requires different types of rules, which vary between areas in California. For instance, injection wells used for recharge need to be approved by the relevant regional water quality control board (responsible for preventing pollution of aquifers). Regional boards in Southern California are usually more flexible than in the Central Valley, which has blocked aquifer recharge with treated drinking water, over concerns about the effects of chemicals on the aquifer. Other local concerns are the potential effects of groundwater exports on local economies which have caused limitations in the use of groundwater transfers.

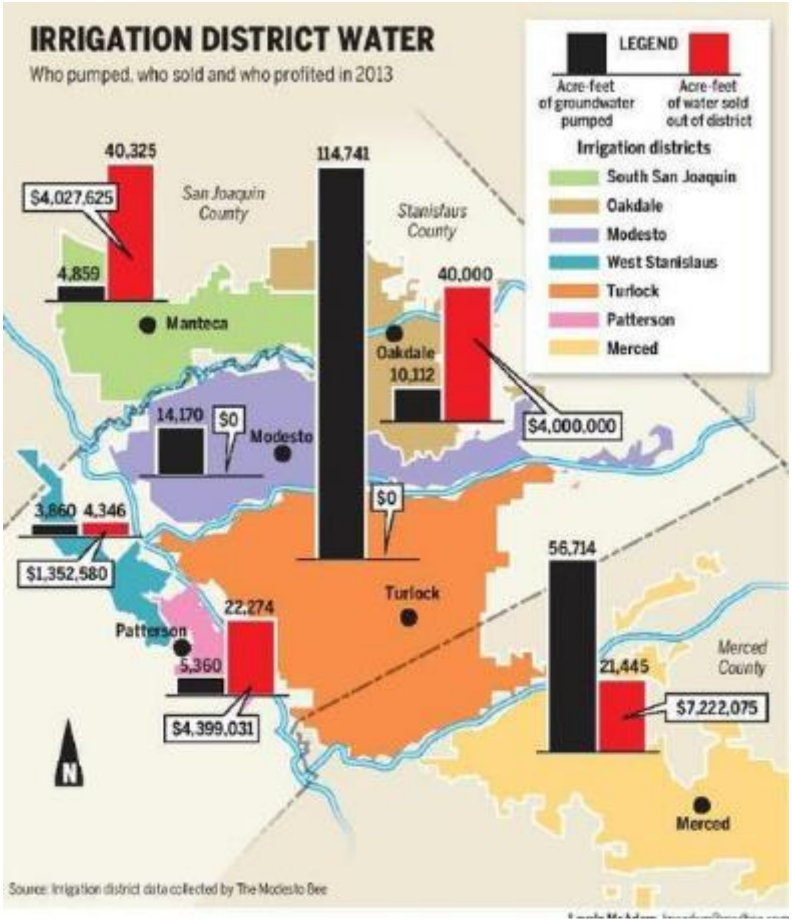
Within California, the Department of Water Resources counted in 2012 at least 89 agencies engaging in groundwater recharge programs. Reporting of this type of activities is however sometimes difficult as local agencies mistrust state intervention and oversight of groundwater. Since 2009, Senate Bill X7-6 required local entities to report groundwater levels to the Department of Water Resources but many local officials fear coming state efforts to manage groundwater.[153]

In Southern California for example, the Metropolitan Water District of Southern California has withdrawn, since 2001, over 72,000 acre-feet of groundwater from three different groundwater banks. Kern County, just below the Tulare Lake Basin has 11 groundwater banks. The oldest of these banks, the Semitropic Water Storage District, is the largest bank storing water for entities located outside the county, wishing to import water, and it operates an informal conjunctive use program for farmers and uses the proceeds from its banking operations to lower the costs of imported surface water, to make it more attractive to farmers who would otherwise pump groundwater. Between 1990 and 2006, groundwater banks in the Kern County accumulated nearly 3 million acre-feet. Half of the groundwater stored is for usage within the county (mostly agriculture) and the rest is transferred outside (28 percent to Southern California, 18 percent to the Bay area, and 8 percent elsewhere in the San Joaquin Valley).

[153] Lusvardi, W. 2014 "Gov. Brown, legislature push groundwater regulation", http://calwatchdog.com/2014/03/14/gov-brown-legislature-push-groundwater-regulation/ (Accessed 18th March 2014). This legislative push was put on paper by the California Legislative Analyst Office in March 2014 by releasing a study on improving the management of California's groundwater, recommending comprehensive monitoring system for extractions, establish management areas with jurisdiction over groundwater basins, and bringing in state-wide groundwater abstraction permits (Legislative Analyst Office 2014 Improving management of the State's groundwater resources, March 11th, 2014, http://www.lao.ca.gov/handouts/resources/2014/Groundwater-Resources-03-11-14.pdf, accessed 18th March 2014).

This situation of groundwater banking and water markets in California can generate large revenues for irrigation districts which can act as incentives to sell surface water at a very profitable price and shift to groundwater pumping to compensate for the surface water sold (Figure 61). In the San Joaquin River Basin in the Central Valley, groundwater users have been selling groundwater to agencies outside the district since 2000 for an estimated value of 140 million USD.[154] The Merced irrigation district, even though it sold over 7.2 million dollars' worth of surplus water to other water districts, pumped 56,714 acre feet of groundwater to satisfy its own demand.[155]

Figure 61. Irrigation district groundwater pumped and sold in 2013 in the San Joaquin Valley



Source: The Modesto Bee, http://www.modbee.com/2014/03/15/3242022/irrigation-district-selling-water.html (accessed 18th March 2014).

[154] The Modesto Bee, http://www.modbee.com/2014/03/15/3242022/irrigation-district-selling-water.html (accessed 18th March 2014).
[155] Ibid.

Figure 62. Water projects in California

Source: Osuji et al. 2003.

1.4 Legislative reform in California after the 2014 Drought episode

Due to the 2014 drought episode, with almost 60 percent of the state considered under Exceptional[156] drought circumstances by August 2014, the state of California is considering

[156] The NOAA (National Oceanographic and Atmospheric Administration) of the United States defines the different thresholds for drought circumstances according to the Palmer Severity Drought Index. This index is an estimated measuring soil moisture deficiency by combining temperature, precipitation, evaporation, transpiration, soil runoff, and soil recharge data. According to this index, Exceptional droughts are defined with an index between -5.0 and -5.9 (National Drought Overview, National Climatic Data Center, NOAA, http://www.ncdc.noaa.gov/sotc/drought/2014/2#det-pdi, Accessed 21st August 2014).

regulating groundwater as the state has no comprehensive code for managing groundwater.[157] Groundwater can provide up to 60 percent of the water supply in California during drought episodes so, with a lack of precipitation over 2013 and 2014, California has registered an increase in the number of wells drilled as well as a record number of wells going dry and water tables dropping as much as two meters per week in parts of the San Joaquin valley.[158] It has been estimated that during this drought episode, groundwater reserves have provided up to 75 percent of water which previously came from surface sources.[159]

As a result, California's lawmakers put forward Assembly Bill 1739 in February 2014 and amended in the Senate in August 2014 with its approval signed by the governor in September 2014. This new bill requires water agencies to develop management plans and require the 127 groundwater basins with the highest water use to manage the resource (the 23 adjudicated basins are exempted). According to the Bill, local officials will have until 2017 to form a management agency and by 2020 the agency will have to submit a plan for addressing the monitoring of water levels, preventing sea water intrusion, and the collection of data.[160] Agencies would have more enforcement powers as the bill would also authorize groundwater sustainability agencies to conduct inspections of wells. Groundwater management plans will have to address how to halt groundwater overdraft and each basin will have two decades to meet the objectives of the plan.[161]

1.5 Groundwater management and governance in Los Angeles[162]

The first example of adjudication of groundwater rights in California originated from a court ruling between the city of Pasadena and the city of Alhambra in 1937. In order to determine the boundaries and physical limitations of the shared aquifer between the two cities, the court asked the California Division of Water Resources to establish the boundaries of the aquifer and determine a safe yield. In light of uncertainty of what the court would do, the two parties began an informal negotiation leading to an agreement between almost all of the parties. The agreement asserted that all parties would be granted prescriptive pumping rights proportional to the actual safe yield of the basin. The agreement added that the rights would be transferable. As not all the parties agreed to sign off on the stipulation, a brief trial incorporated the stipulated agreement in its final judgment (Steed 2010).

District courts in California still control groundwater rights through the adjudication process of court orders. However, rather than monitor groundwater use directly, the courts nominate

[157] "California lawmakers move to protect the state's collapsing groundwater supply", The Circle of Blue, 20th August 2014, http://www.circleofblue.org/waternews/2014/world/california-lawmakers-move-protect-states-collapsing-groundwater-supply/ (Accessed 21st August 2014).

[158] "Drought drives drilling frenzy for groundwater in California", WBEZ91.5, 14th July 2014, http://www.wbez.org/series/front-and-center-water/drought-drives-drilling-frenzy-groundwater-california-110483 (Accessed 21st August 2014); "California drought spurs groundwater drilling boom in Central Valley", National Geographic, 15th August 2014, http://news.nationalgeographic.com/news/2014/08/140815-central-valley-california-drilling-boom-groundwater-drought-wells/ (Accessed 21st August 2014).

[159] "California lawmakers considering historic shift in groundwater policy", The Los Angeles Times, 9th August 2014, http://www.latimes.com/local/politics/la-me-pol-water-20140810-story.html (Accessed 21st August 2014).

[160] "California lawmakers move to protect the state's collapsing groundwater supply", The Circle of Blue, 20th August 2014, http://www.circleofblue.org/waternews/2014/world/california-lawmakers-move-protect-states-collapsing-groundwater-supply/ (Accessed 21st August 2014).

[161] Ibid.

[162] Unless stated otherwise, this section is based on Steed (2010).

water masters. Different organizations can perform such role. In Los Angeles, for the West Coast and Central Basins, the California Department of Water Resources performs the water master functions, whereas the Raymond Basin and Main San Gabriel Basins have created their own management operations, including their own watermaster (Steed 2010).

1.5.1 The adjudication of basins in Los Angeles

As an example of California's complex groundwater polycentric governance, the West Coast Basin in Los Angeles is governed by a court judgment but is monitored by the California Department of Water Resources serving as a watermaster. Additionally, some of the pumping records are gathered by the Water Replenishment District of Southern California, and also for groundwater recharge. However, aquifer recharge facilities (including recharge wells along the coast) are owned and operated by the Los Angeles Department of Public Works. Recycled water used for aquifer recharge is provided by the Sanitation District of Los Angeles County and the West Basin Municipal Water District, although its use is governed by the California Department of Health. The overall water quality of the basin is monitored by the Replenishment District and the California State Water Quality Control Board (Steed 2010).

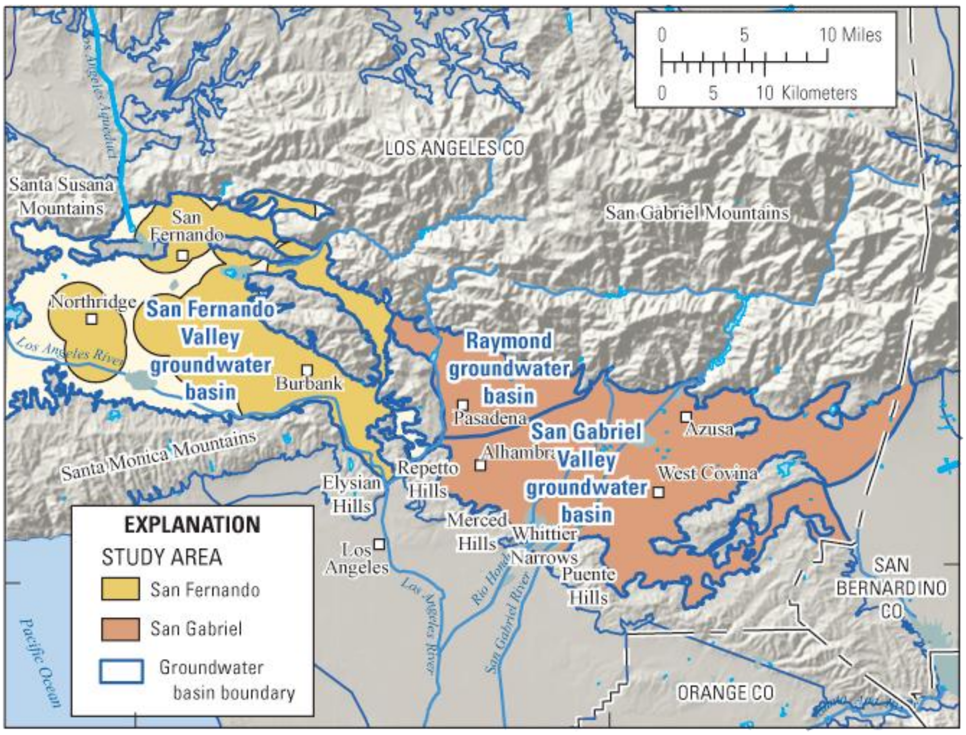
In the Raymond Basin, located north of Los Angeles and including the city of Pasadena (Figure 63 and Figure 64), the court ruling of 1944 first appointed the California Department of Water Resources to monitor that all parties complied with the stipulated agreement. The court judge also created a watermaster to monitor and enforce the judgment's provisions. The California Department of Water Resources was assigned this role but was assisted by a newly created advisory board made up of pumpers to provide input to the watermaster on questions of policy and budget. The costs of the watermaster services were split fifty percent each between the state of California and the groundwater users whilst the costs of the advisory board were left to be covered by the groundwater users. Each groundwater user was asked to keep records of pumping activities. This information was to be provided to the watermaster who would compile each year a report on the basin conditions and submit it to the court (Steed 2010).

Pumping levels for the Raymond Basin were adjudicated in 1945 as a 30 percent reduction of the 'present unadjusted rights' that occurred during the previous five years. However the establishment of quotas based on historic use tended to promote, according to Lipson (1978: 12), "a race to the pump house to establish a high quota" as users' attorneys advised them to "keep pumping despite the cost, since reduced pumping might damage their groundwater rights" (Lipson 1978: 29). Between 1945 and 1955 pumping levels were set at the safe yield of 21,451 acre-feet per year. Then in 1955 the safe yield was revised and increased. This revision of the safe yield set by the Judgment happened as a request from the pumpers in 1950. In response to the request, the court appointed the California Department of Water Resources to act as a referee and review the basin's safe yield. The findings of the Department of Water Resources deemed the safe yield as too low and submitted a new estimate of 30,622 acre-feet per year. In light of this finding the court modified the initial judgment and in April 1955 proportionally increased the parties' pumping rights to bring them in line with the newly set safe yield (Steed 2010) (Figure 65).

Figure 63. Groundwater basins in the Los Angeles area

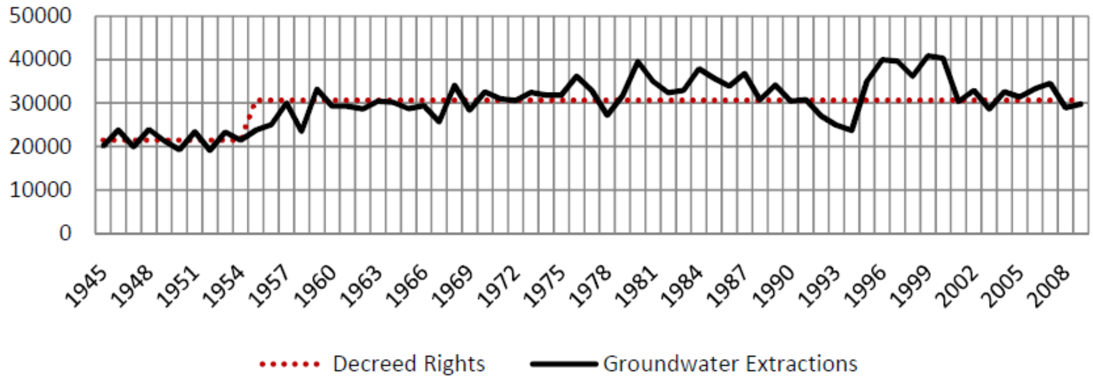
Source: USGS.

Figure 64. The San Fernando Valley, Raymond, and San Gabriel Valley groundwater basins (north of the Central Basin, Los Angeles)



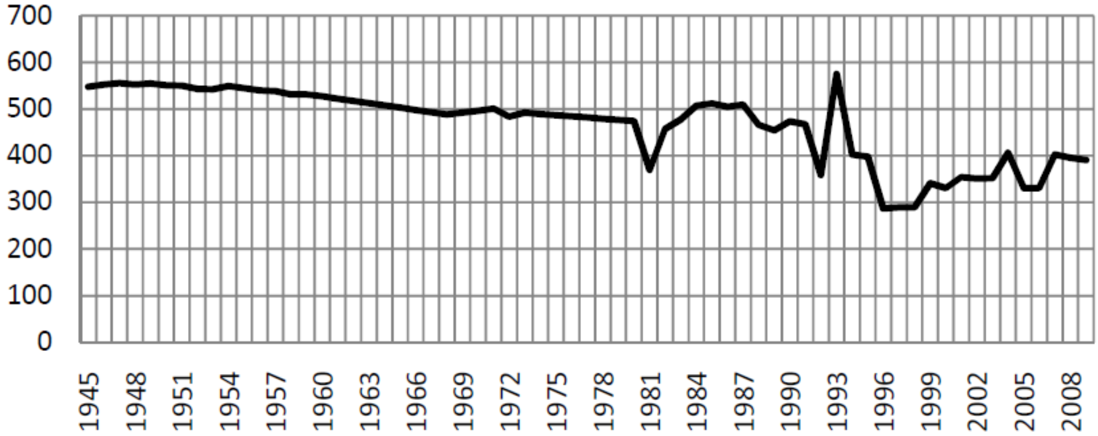
Source: USGS.

Figure 65. Groundwater extraction levels and decreed safe yield for the Raymond Basin, Los Angeles between 1945 and 2009 (in acre-feet)



Source: Steed 2010.

Figure 66. Groundwater levels in the Raymond Basin, Pasadena sub-area (1945-2009) (in feet)

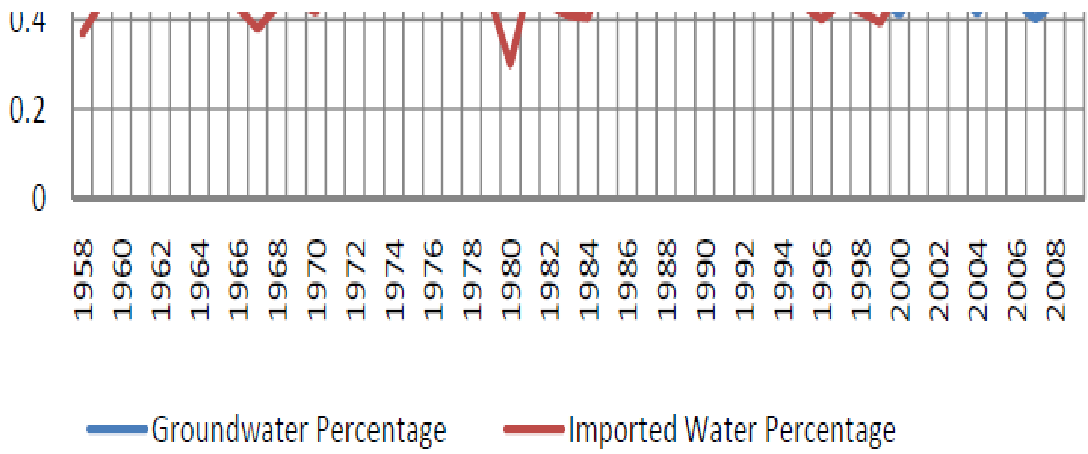


Source: Steed 2010.

In 1982 the state decided to reduce its contribution from half to one third. This decision meant that pumpers had to cover two thirds of the costs of the watermaster services. The subsequent modification of the judgment reassigned the role of watermaster to the Raymond Basin Management Board, the successor to the Raymond Basin Watermaster Advisory Board which had been performing monitoring activities as part of a voluntary program to control pumping patterns in over-abstracted areas of the Basin since the 1960s (Steed 2010).

Despite the regulation of wells and the control of pumped volumes in the Raymond Basin, the stabilization in groundwater abstracted is also due to the increasing dependency on imported water, with up to 60 percent of water used in the basin from the Colorado River (Figure 67). The Watermaster Board is the enforcement arm of the Court adjudication judgment which established water rights and the responsibility for groundwater quantity management in the basin. Violations of the Judgment are brought before by the court for sanctioning.

Figure 67. Percentage of groundwater and imported water used in the Raymond Basin

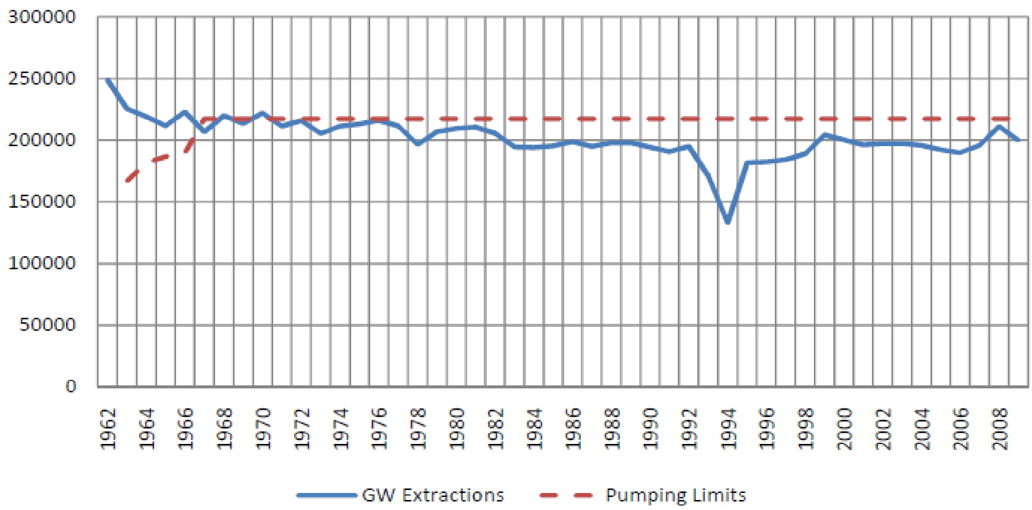


Source: Steed 2010.

1.5.2 Limitation of groundwater pumping by court in Los Angeles and technological fixes

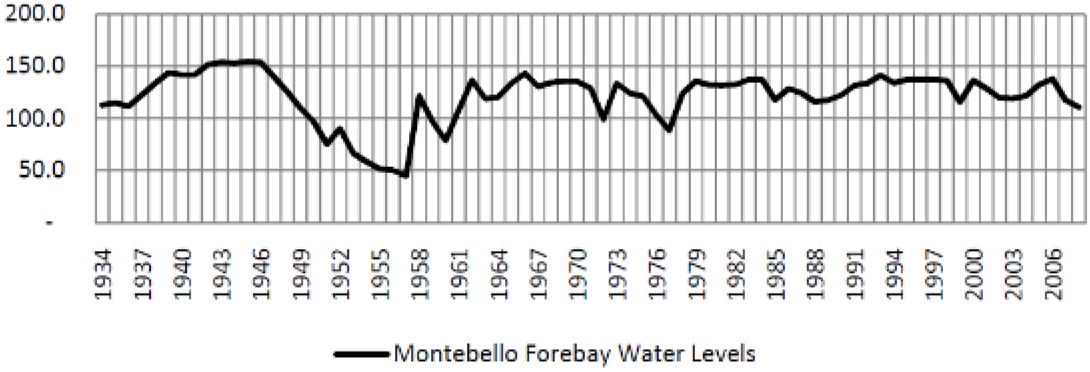
Another of the groundwater basins in the Los Angeles metropolitan area, the Central Basin (Figure 63), shows groundwater abstraction levels complying with the court's stipulated safe yield (Figure 68). Although the watermaster has the authority to bring the parties to the court in case pumping limits are violated, this authority has been discretionary and considered as an extreme exception. Historically many of these issues have been resolved by issuing warnings and demanding the offending parties to pay into the basin exchange pool. More recently, the wastermaster has demanded that those parties exceeding their established pumping limits reduce their pumping in subsequent years to compensate.

Figure 68. Groundwater abstraction levels and pumping limits for the Central Basin (in acre-feet)



Source: Steed 2010.

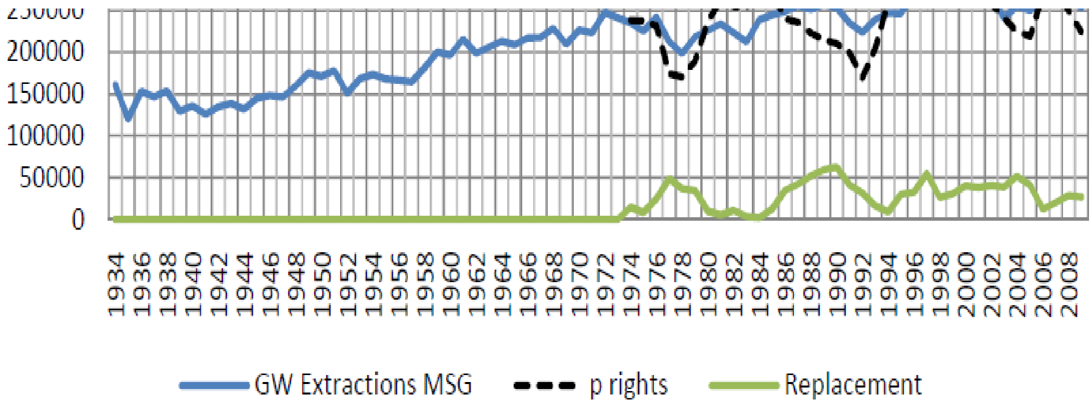
Figure 69. Central Basin groundwater levels (1934-2009) (in feet)



Source: Steed 2010.

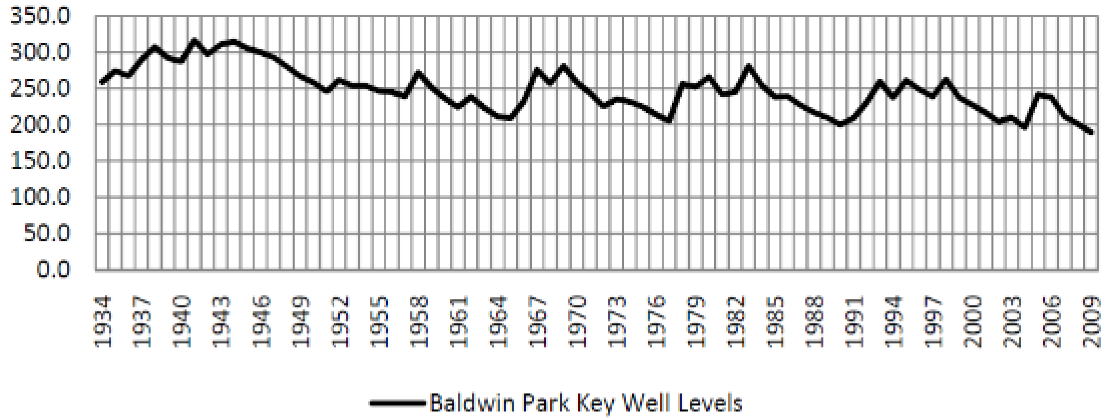
For the Main San Gabriel Basin (Figure 70), the setting is slightly different and the initial judgment allowed that if there was excessive pumping the user could provide make-up surface water taken from water rights, and sell it to agencies in the Central District delivered to lined stream channels and conveyed to lower areas of the basin. In the case of this basin, abstraction levels usually exceed the operating safe yield due to the delayed effect of excess abstractions being carried over to subsequent years. However, the use of aquifer recharge and imported water has compensated for the increases in pumping levels over the defined operating safe yield. The watermaster may impose a payment to pumpers over-abstracting groundwater (i.e. a replacement assessment) in order to purchase mainly imported water for infiltration, to replace the additional groundwater pumped (Figure 71).

Figure 70. Groundwater extraction, production rights and replacement water in the Main San Gabriel Basin, Los Angeles (in acre-feet)



Source: Steed 2010.

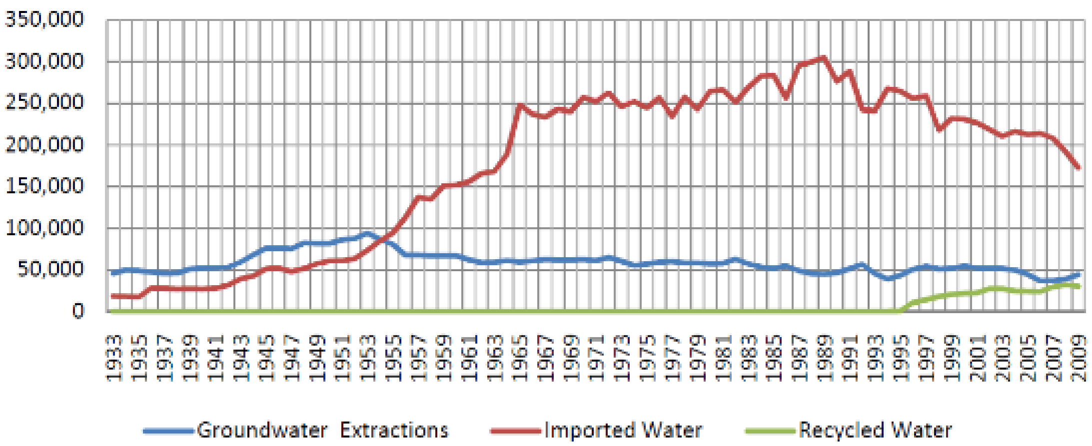
Figure 71. Groundwater levels in the Main San Gabriel Basin (1934-2009) (in feet)



Source: Steed 2010.

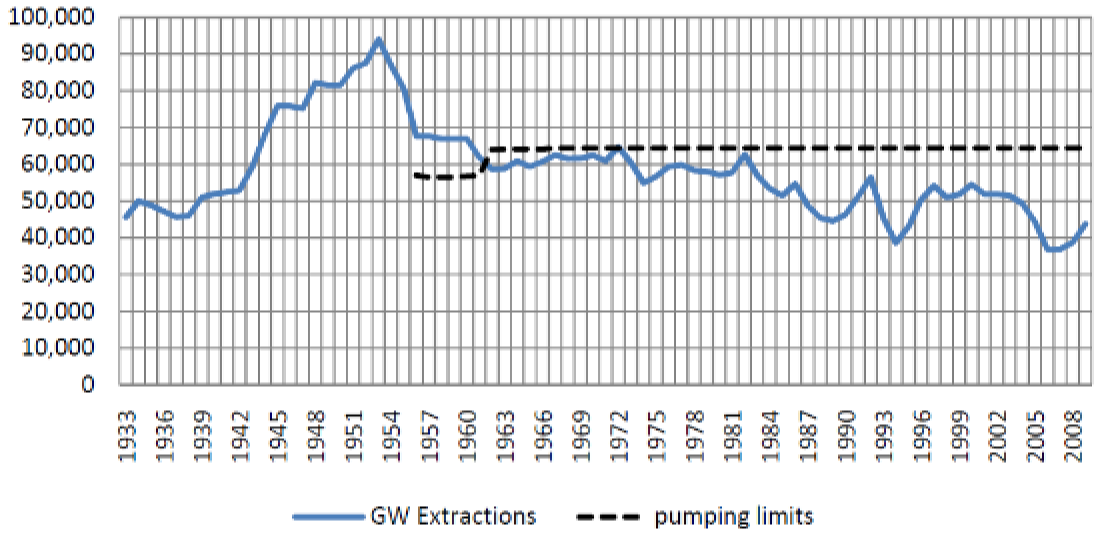
The stabilization of groundwater abstraction levels in Los Angeles was ultimately made possible by the arrival of new sources of water from inside and outside the basin (Figure 72). As Lipson (1978) wrote about the West Coast Basin, the adjudication of the basin which involved a cut back in pumping through the agreement of all parties, rested on the availability and possibility to import water. Such technological fix, the increase of imported water and recycled water in the overall water production balance of Los Angeles, suggests that the political/financial capacity of increasing water production at the basin scale is paramount to solving internal institutional issues, improving the sustainability of the city's water use, and allowing its citizens to sustain potentially environmentally threatening water consumption patterns and only delay in time necessary structural changes.

Figure 72. Water sources for the West Coast Basin, LA (1933 to 2009) (in acre feet)



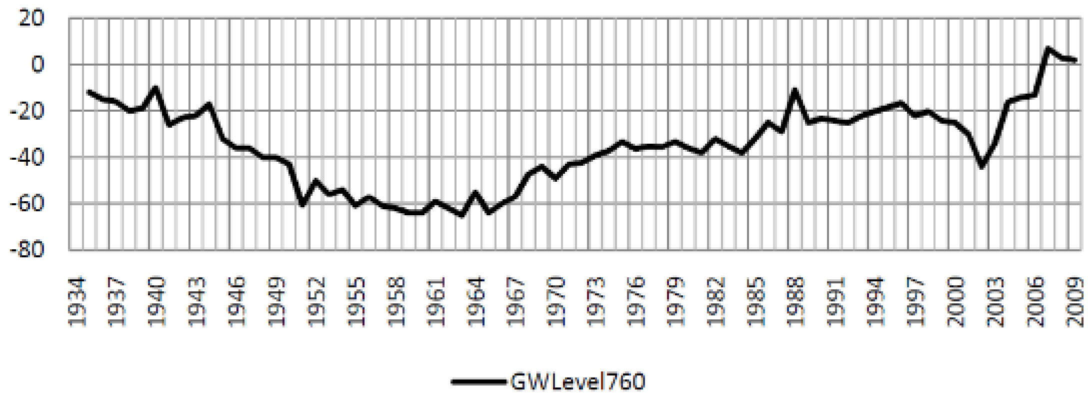
Source: Steed 2010.

Figure 73. West Coast Basin pumping and adjudication limits (in acre feet)



Source: Steed 2010.

Figure 74. Groundwater levels in the West Coast basin (1934-2009) (in feet)



Source: Steed 2010.

1.5.3 Institutional change, groundwater development, and corruption in Los Angeles

According to Steed (2010), in the Los Angeles area many institutional changes occurred as a direct response to disturbances, but these disturbances appear to be neither a necessary nor a sufficient condition for institutional change to occur. Disturbances such as dropping groundwater levels and seawater intrusion led to the adjudication and creation of institutional, managerial and technical mechanisms for importing water or developing aquifer recharge programs. More recently, water scarcity and the high cost and instability of imported water, have also facilitated the creation of mechanisms to provide recycled water for direct use (Steed 2010).

Despite these disturbances and a considerable flux of additional people moving to the area, groundwater abstraction levels in the four basins found in Los Angeles and reviewed above, have remained by and large stable since the 1960s. This finding leads Steed (2010) to suggest that water quality and quantity are sufficient to make pumping worthwhile and that the institutional and technological responses (via the creation of special districts and new sources of water) have been sufficient to ensure water access despite the wide variety of disturbances over time. These disturbances also seem to be one of the most important drivers of change for institutional settings in the Los Angeles groundwater basins. However these changes do not occur immediately following the disturbance but need some time to adjust showing substantial initial inertia. These responses, on the whole, have maintained the basins' quality and quantity. Water users created associations to develop management decisions to respond to the problems associated with falling groundwater tables, and make decisions regarding the management of the basins and for establishing the special districts for importing water from distant sources.

However, as Zetland (2009) purports, an iron triangle of bureaucrat-politician-developer interests in the Metropolitan Water District (MET) in Southern California has sought to defend a management status quo not suitable for water scarcity situations and aimed at creating unsustainable water demand, 'pro-growth' interests in charge of an 'aqueduct empire' (Erie 2006). The MET is a special district constituted as a consortium of 26 cities and water districts created originally in 1928 by 11 cities, and instrumental in granting access to the Colorado River to the area of Los Angeles. It provides water mostly from imported sources to several Municipal Water districts with nearly 19 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino, and Ventura counties.

The Metropolitan Water District fostered the increase of water sales to customers after it over-dimensioned its facilities because it overestimated the city's population and miscalculated water demand (Erie 2006). The public utility faced a flood of unsold water and therefore lowered its prices in the early 1950s below the local cost of water in order to cover operating losses through sales increase. Furthermore, according to Zetland (2009), the expansion of the MET was sustained by a rent-seeking iron triangle driving the expansion of the MET's operations and area for fear of alienating powerful economic and political actors depending on regional boosters and votes. This enterprise had become a 'shadow government' according to Gottlieb (1991 in Erie 2006:49) dominated by representatives of the city, establishing "policies that were more favorable to newly developing areas rather than the city itself". As Gottlieb and FitzSimmons (1992) also noted, the formulation of water policy in California by local agencies is the product of local interests "committed to using water to achieve economic growth" (Shelton 1992: 473).

Another instance of deviant organizational behavior is found in the West Coast Basin and the West Basin Water Association. The West Basin Water Association is the most important non-governmental entity operating in the Los Angeles area across the West Coast Basin. It was created in 1946 and initially included twenty members representing municipalities, oil companies, and private water companies pumping groundwater from the West Coast Basin. Currently thirty one organizations are members. The main function of the West Basin Water Association is to provide a forum for members to discuss and resolve conflicts. The association has taken part in adjudicating water rights, creating injection wells, forming the West Basin Municipal Water District, created to facilitate access to imported water for a number of smaller municipalities, unincorporated areas of the County and other water providers. The West Basin Water Association also created the Water Replenishment District of Southern California which has been recharging the depleted Basin since 1959 (Steed 2010).

The separation of activities and mandates into special districts has led to the growth in power of these special districts as directors of water policy-makers, with the 'bureaucrats' within these special agencies seeking to establish and appropriate more functions and a more important role for their agencies (Steed 2010). The West Basin Municipal Water District engaged in a variety of entrepreneurial activities in order to diversify the portfolio of water available sources within the West Basin (including water recycling, water purification of brackish water and desalination). The various activities of the different special districts within the LA area have duplicated infrastructures and developed redundancies, such as two agencies operating desalination plants close to each other (Steed 2010).

With increasing activities and projects as well as owners of strategic infrastructure (e.g. water recycling plans and desalination plants), these agencies manage important budgets. The West Basin Municipal Water District operates on a yearly budget of over 100 million dollars. This increase in funds has led to some issues related with corruption in Los Angeles. Managers have been subject to investigations due to rent seeking and corruption as the California State Auditor investigated the district in 1999. These types of associations and special districts have sought more power over the years, as influential policy actors. The audit found that the amount of reserves needed to be replenished as part of a three-year budget plan had been overestimated (at 20 Mm3, or twice as much as the targeted reserve) and that the amount of cash available to the district was too high (Steed 2010).

As Steed (2010) wrote, with the population of the Los Angeles area increasing, the control of water has become increasingly important, thus leading to the politicization of the water industry with water management roles sought after. The position of water manager has been invested with a "higher profile and attractive to different individuals" and "[w]ater district boards and staffs are now populated by individuals who view the job as a launching pad for a political career, or a landing pad after serving in higher office" (Steed 2010: 377).

In August 2013 the FBI was still investigating the connections and personal favors between various members of one family with close political connections and the Central Basin Municipal Water District, which granted consultancy contracts to members of that family via the pressure of the state senator (the brother of the consultant awardee) as well as donations to four of the five board members of the Central Basin Municipal District.[163] Legal suits in the Central Basin Municipal Water District also include a lawsuit by former Chief Operating Officer for wrongful termination, contract disputes, and contributing to the district's fiscal instability. The current debt of the district is currently at least 9 million USD. An independent audit on the district's financial records found deficiencies in the bidding practices as it did not follow its policy of obtaining enough bids for contracts as well as the use of district credit cards for personal purchases. The review of financial records was also reviewed once a year instead of quarterly.[164]

2 Oregon and Florida

2.1 Oregon's groundwater mitigation program

The Deschutes basin in Oregon has experienced rapid population growth and urbanization in the last 40 years, shifting water uses from agriculture to urban uses, recreational and hobby-farming uses, while increasing ecosystem health concerns in the basin. It is a basin covering around

[163] FBI continues probe into Central Basin water district's records, Los Angeles Times, August 21 2013, http://articles.latimes.com/2013/aug/21/local/la-me-central-basin-20130822 (Accessed 17th February 2014).

[164] Central Basin Municipal Water District in More Hot Water, February 7, 2014, http://www.kcet.org/updaily/socal_focus/commentary/where-we-are/central-basin-municipal-water-district-in-more-hot-water.html (Accessed 17th February 2014).

10,700 square miles in central Oregon and a groundwater driven hydrosystem (Gannett et al. 2001). Many streams are directly fed by groundwater discharges and that base flow is the main source of streamflow (Cooper 2008). Surface streams have been administratively closed to additional appropriation for many years and surface water is not available to support further development (Gannet et al. 2011). As a result, groundwater is relied upon to satisfy growing demands (ibid.).

Amendments in 1995 to the Scenic Waterway Act (adopted in 1970)[165] required the examination of groundwater rights and their impact on surface water flows when considering new applications for groundwater abstraction (Gannet et al. 2011). It was dictated that if groundwater use for human consumption and livestock uses cumulatively affected streamflow by 1 percent of average daily flows (or one cubic foot per second, whichever is less), new groundwater permits would not be approved and that further groundwater regulation would be required including mitigation measures by users. This is unless the Water Resources Commission and other state departments involved, decide unanimously that the amount can be exceeded or that exceeding that amount "will not significantly impair the free-flowing character of these water in quantities necessary for recreation, fish, and wildlife."[166] In 1998 the Water Resources Department activated this rule as a result of preliminary results on the hydrogeology of the basin by the US Geological Survey. New groundwater applications were put on hold while the Department explored various management options for the basin. In 1999 the Department convened a group of stakeholders in order to develop mitigation strategies to offset the reduction of water in the basin. As a result of these discussions House Bill 2184 was passed, authorizing a system of mitigation credits and exchange (State of Oregon 2008).

The Deschutes Groundwater mitigation set up in 2002 by the Oregon Water Resources Department program used a combination of regulatory and market-based mechanisms to mitigate the impacts of groundwater use in the basin. The program was later ratified by House Bill 3494 in 2005. The program capped new groundwater pumping to counter their effect on surface water flows with the objective to maintain surface flows for scenic waterways as well as senior water rights (including in-stream water rights). It also aimed at facilitating the restoration of flows in the middle Deschutes River and related tributaries as well as sustaining existing water uses and accommodating growth through new groundwater development.

This scheme could be considered as a mechanism to conjunctively manage surface and groundwater whilst allowing for new uses by establishing a mechanism to trade surface water rights for groundwater pumping rights. The scheme mandates that the calculated amount of consumptively used water must be compensated with an equal amount of water left in stream or through another equalizing water transfer further downstream (Lieberherr 2008).

The rules from the Water Resources Department identify several projects that can be used to provide water: 1) instream leases;[167] 2) time-limited instream transfers; 3) permanent instream

[165] The Scenic Waterway Act required the State of Oregon to maintain the “free flowing character” of scenic waters “in quantities necessary for recreation, fish and wildlife uses.” The Act also designated as Scenic Waterways various portions of the Deschutes River and Basin Tributaries.

[166] Oregon Legislative Assembly, Senate Bill 172, 2001, http://www.epa.gov/sites/production/files/2015-11/documents/oresb172.pdf (Accessed 28th February 2016).

[167] Instream leases is a voluntary programme for water users at risk of forfeiture of their water right due to non-use, can transfer water to instream uses through this programme. Eligible water rights include “rights to use surface water and rights to store water in a reservoir”. Rights can be leased for no more than 5 years or in the case of irrigation rights, no

transfers; 3) allocations of conserved water; 4) aquifer recharge; 5) releases of stored water (State of Oregon 2008). For each project submitted, the Department identifies the amount of water that can be used for mitigation purposes and the resulting water, expressed in acre-feet, is referred by the Department as 'mitigation water' or 'mitigated credit' (one acre-foot of mitigation water is equivalent to one mitigation credit).

When new groundwater permits are submitted, the Water Resources Department notifies the applicant of their ‘mitigation obligation’, expressed as a volume of water in acre-feet equivalent to the consumptive portion of the use proposed in the application. Mitigation water must then be provided in the amount and location zone specified by the department. These zones are based on where the proposed use will primarily impact surface water flows. Each applicant has then five years to provide the required mitigation water from the date the order is issued by the Water Resources Department. Applications having requested mitigation credits have also 5 years to the credits and provide documentary evidence. The final order issuing the permit will expire if mitigation is not provided. The maximum cumulative amount of groundwater to be abstracted issued through permits by the Department in the Deschutes basin was defined as 200 cubic feet of water per second. As of 2008, the Department had yet to allocate 115 cubic feet per second through new permits (State of Oregon 2008). But pending applications as of January 2013 amounted to 57.63 cubic feet per second, (Sussman 2013).

This program allowed the establishment of a mitigation bank and mitigation credit exchange. Users can obtain mitigation credits from credit holders (these are either directly from individuals or from two mitigation banks). Mitigation banks are established as a voluntary non-profit brokerage cooperative. These credits can be permanent credits or temporary mitigation credits. These mitigation credits are a means of encouraging individuals and institutions to invest in mitigation projects. Credits earned can be held, applied, sold, or transferred. The impacts of the scheme, studied after 5 years of its implementation, showed a gain of more than 39 cubic feet per second as a result of permanent and temporary mitigation projects and an improvement by as much as 27 cubic feet per second in overall streamflow in some areas due to these mitigation measures (State of Oregon 2008).

The implementation of this mitigation program was however controversial, especially amongst environmentalist groups trying to protect Oregon’s rivers. In 2002, environmentalist groups led by the Water Watch Group filed a lawsuit against the Water Resources Commission sustaining that the Deschutes Basin Water Plan abandoned "the state’s responsibility to protect the river and instead focus on making it easier to get water rights. In so doing they violate two key river protection laws, the State Scenic Waterway Act and the Instream Water Rights Act."[168]

The Court ruling stated that the program, aimed at 'mitigating' the impact on streamflows of new groundwater permits, "did not offset such impacts on protected streamflows" and allowed for further reductions to take place.[169] For the judge, "the rules wrongly emphasized average annual water volumes in the river and failed to take into account the need to maintain flows at the specific times needed for fish spawning and rearing".[170] The ruling in favor of the plaintiffs

more than 5 irrigation seasons. Leases can be renewed unlimited times (Oregon Water Resources Department, http://www.oregon.gov/owrd/pages/mgmt_leases.aspx, Accessed 29th January 2015).

[168] http://www.bendbugle.com/2002/11/river-firms-conservationists-sue-to-block-deschutes-basin-plan/ (Accessed 19th March 2014).

[169] http://www.oregon.sierraclub.org/tracker/HB3494.html (Accessed 19th March 2014).

[170] http://crag.org/content/news/wa20050519.pdf, (Accessed 19th March 2014).

meant that the state could no longer issue water rights for groundwater across a large section of the Deschutes Basin.[171]

Despite this Court ruling in 2005, the state, via House Bill 3494, validated this plan and enacted it as Law with the approval of all but one member of the State House of Representatives. Also, even though House Bill 3494 in 2005 ratified the groundwater mitigation program, it also included a provision repealing the rules in January 2014. A report by the Water Resources Department on that House Bill in 2008 stated however that stakeholder representatives had raised concerns about the end date of the Mitigation programme, creating too much risk for applicants and problems for long-term water supply planning (State of Oregon 2009). During the 2011 Legislative Session, House Bill 3623 extended the mitigation rules deadline deadline to January 2029.

2.2 Tampa, Florida

In Tampa Bay, Florida, human population growth also led to changes in the quantity, quality, location and timing of instream flows in rivers and freshwater inflows to the coastal zone (Yates et al. 2011). Other anthropogenic activities further altering the hydrologic characteristics of the watershed include urban development increasing the amount of impervious surfaces, hardening of stream banks, diversions and water and groundwater withdrawals as well as the construction of dams and reservoirs, and discharges of municipal and industrial wastewater and irrigation water altering the timing, location and quality of freshwater (Yates et al. 2011).

Since the early 1950s, increasing amounts of groundwater and surface water abstracted from the basin to provide potable supplies and support agricultural and industrial uses have caused hydrologic and environmental impacts in parts of the Tampa Bay watershed. In order to respond to this impending crisis, the Florida legislature passed the Florida Water Resources Act requiring the different water management districts to establish minimum flows and levels for surface water bodies and aquifers to protect ecosystems and livelihoods. This law also required the different water management districts to develop regional management plans to meet water demand over a 20-year planning horizon, identifying water supply sources and water resource development projects to be implemented to meet those future demands.

The reduction of the impacts on the Tampa Bay ecosystem and watershed from groundwater pumping was obtained however via the development of new alternative surface-water-supply sources bringing the abstraction of groundwater from 11 well fields from 158 Million gallons per day from 1995-2002 to 90 Million gallons by the end of 2008 (Yates et al. 2011). Additionally, increased re-use of treated effluents for irrigation and industrial uses and implementation of aquifer storage and recovery technologies to provide more consistent year-round water supplies are also part of the supply alternatives considered.

3 Discussion

The brief review of some examples of groundwater management in the United States shows a wide diversity of management scenarios and legal contexts. In some cases grass-roots associations have been able to empower users and emerged as a reaction to state attempts to regulate and legislate groundwater. However, this diversity and richness in local self-management did not happen within a vacuum of state rule and public authority.

[171] http://crag.org/content/news/wa20050519.pdf, (Accessed 19th March 2014).

In California, courts have an active and important role in ruling about groundwater management and allocation. The case of California, as analyzed by Blomquist (1992) and Steed (2010), demonstrates a high level of polycentric governance with different instances and levels of institutional rules with an important role nonetheless of state organizations and departments providing knowledge and information to users to rule themselves and agree upon groundwater sharing practices. With the role of watermasters, the state via different public departments is established as a guarantor to monitor and enforce court provisions and rulings.

Blomquist (1992), after studying the various institutions involved in southern California groundwater management, concluded that "expertise and wisdom are not the sole province of central public authority, innovation in groundwater management is not limited to the public sector and efficiency is not limited to the private sector, that diversity in governance and management systems is not a sign of disorderliness or impending disaster, and that local water users have considerable ability to self-organize and solve complex problems" (Blomquist 1992: 350).

Groundwater management in Los Angeles and in each of its four groundwater basins underlying the metropolitan area, is governed by rules at various political and administrative levels. This creates, according to Blomquist (1992) and Steed (2010), a polycentric system of governance allowing for a multiplicity of governance arrangements producing different groundwater management and abstraction scenarios based on different initial court rulings. This system accomplishes the conservation and protection of the basins, the monitoring and enforcement of governing rules. However, with its varying governance levels interacting at various nodal points across the groundwater supply system, this system can be sometimes chaotic and messy (Steed 2010) but that, nevertheless, have ensured and provided water to Los Angeles for over half a century. The conclusions derived from the study of Los Angeles suggest that its story reflects a very specific set of historical, cultural, legal and political circumstances which relied on the definition of the ownership and rights of groundwater structured around a judicial system of checks and balances ensuring that the governance regime is applied and respected.

It seems however that the success of groundwater management in some parts of the United States has been based on supply-driven policies to maintain water demand in urban areas. The case of Los Angeles and Tampa, Florida indicate that decisions related to diminishing water demand were relegated in favor of increasing water supply from other areas (imported water for Los Angeles and increasing water production infrastructure in Tampa). The question that remains is, how sustainable is this? As Steed (2010) found in his study, groundwater basins in Los Angeles are beginning to find complications in dealing with changes in the availability of imported water. There is also a lack of trust, corruption from public officials, and competition within agencies and between them. There are also levels of conflict and litigation between basins and between different levels of the governance system.

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Section 2. Groundwater governance in Mexico, Peru, Bolivia, and Chile

Part 1. Groundwater management and user participation in Mexico

1 Groundwater resources and over-abstraction in Mexico

Mexico can be divided into 11 main hydro-geological areas (Velazquez Aguirre and Ordaz Ayala 1994). The Lower California Peninsula (143,000 km2) is made of consolidated rocks and alluvial plains. Groundwater occurs in both formations in small to medium quantities. The main aquifers are found in irregular alluvial formations, with aquifer layers of no more than 100 meters. The Pacific coastal plains in the north consist predominantly of sedimentary rocks and the main aquifers are associated with deltaic areas near the coast. The Western Sierra Madre formation extends along the Pacific Coast from the north down through the centre of the country. Rivers can be perennial or intermittent (e.g. the Nazca river) and can receive large amounts of rainfall. Aquifers are fractured, made of volcanic and basaltic materials and vary in size, draining most of its waters onto surface water bodies and rivers or infiltrates the adjacent hydrogeological areas.

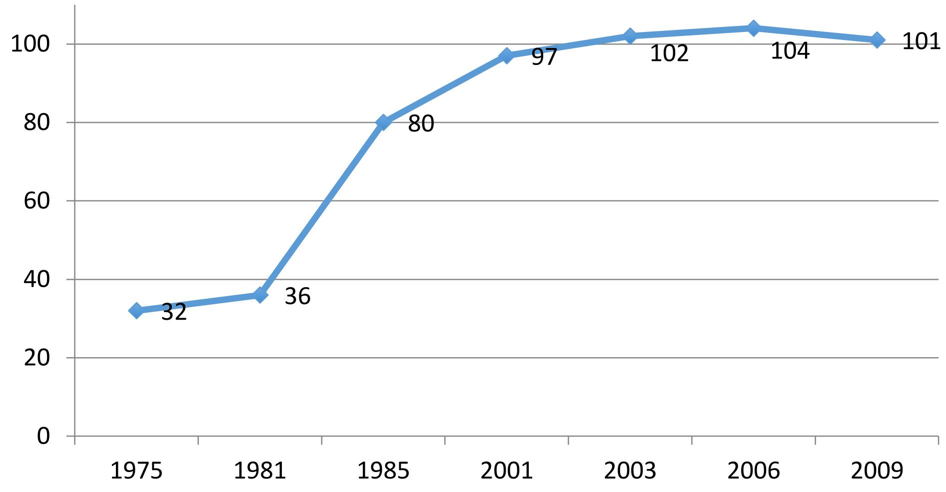
The north of the country also has alluvial basins across an area of around 205,000 km2. Aquifer thickness can vary from 300 down, up to 2,000 meters. The Central Meseta consists of sedimentary and fractured volcanic formations. The Meseta is homogenous in terms of climatic characteristics (temperate and semi-dry climate). Aquifers are mainly found in sedimentary and granular formations and many are currently over-exploited. In the east, the Coastal plains on the Mexican Gulf are mostly sedimentary (consolidated and non-consolidated) with high permeability. The Mexican Volcanic Belt is found just south of the Western Sierra Madre and has high climate variability and varying permeability due to its fractured conditions

The south of the country is well endowed with water resources given its high precipitation record, and aquifer formations in this region are varied and numerous. They consist of sand, clay, and granitic formations in the coastal areas (giving local aquifers thicknesses varying between 8 and 200 meters). The centre of this area consists of a granitic formation bearing small quantities of groundwater due to its low permeability. The Yucatan peninsula mostly consists of limestone formations highly dissolved and fractured, causing large karstic aquifer formations with high infiltration and limited surface water flows.

Irrigation in Mexico uses around 70 percent of the country's water resources and about 50 percent of the farmers use groundwater for agriculture (World Bank 2009). Irrigation is however a very informal sector with around 40,000 irrigation units (generally consisting of one well controlled by one person or by a limited group of people, typically operating on the basis of informal arrangements without legal entity) and 85 legally recognized irrigation districts at the level of the country (representing around 55 percent of the total irrigated land in Mexico with 57 percent of them using groundwater and 43 percent surface water) (OECD 2013; World Bank 2009).

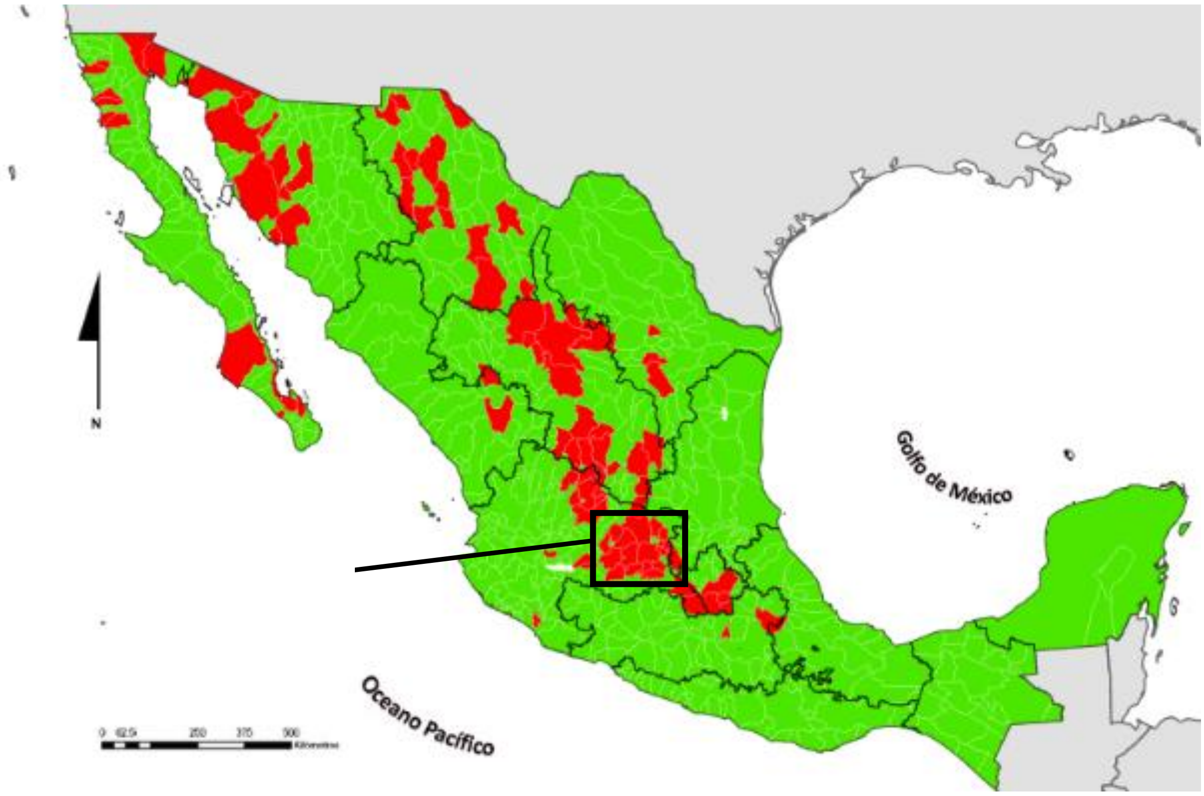
Groundwater over-abstraction in Mexico is concentrated in around 12 percent of the country's total number of municipalities and occurs mainly in the centre and north of the country (Figure 75 and Figure 76). Although groundwater represents around 12 percent of Mexico's water supply, 33 percent of all municipalities in the country are heavily dependent on groundwater (abstracting 70 percent of its water needs from groundwater). The over-abstraction of groundwater in Mexico has also created quality problems. In 2009, CONAGUA had identified 32 aquifers with salinity problems and brackish water, localized mainly in the California Peninsula and the Mexican highlands (Central Mexico), an arid area with high evaporation, low rainfall, and high solar radiation (CONAGUA 2011). CONAGUA had also identified 16 aquifers with seawater intrusion in Mexico (Figure 77).

Figure 75. Evolution of the number of over-abstracted aquifers in Mexico (1975-2009)



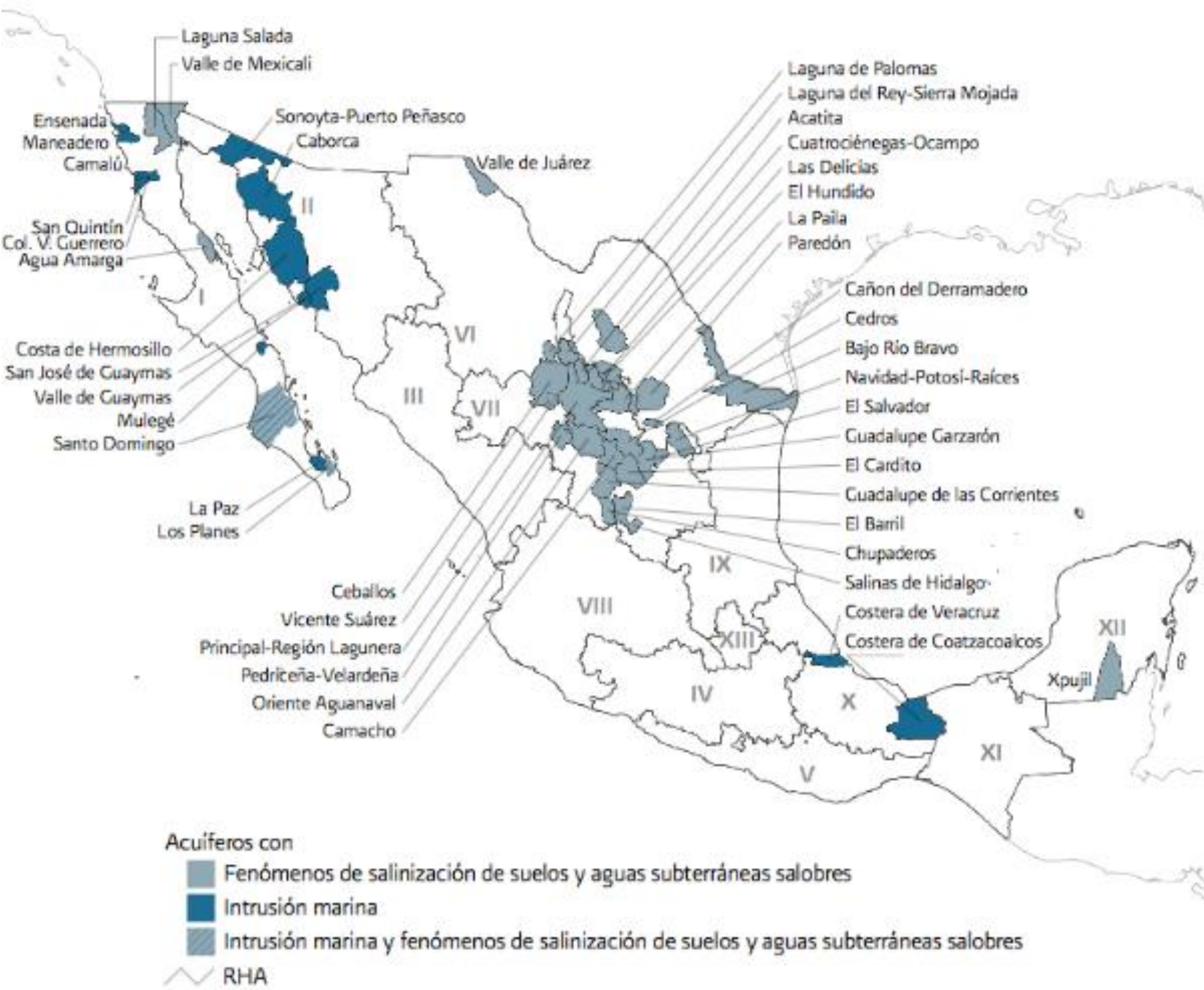
Source: World Bank 2009.

Figure 76. Over-abstracted aquifers in Mexico



Source: CONAGUA 2012.

Figure 77. Groundwater quality issues in Mexico



Source: CONAGUA 2011.

2 Historical regulation and groundwater management in Mexico

The first proper legislation on groundwater in Mexico was issued in 1934 (Dominguez and Carrillo-Rivera 2007). The 'Law of Waters of National Property' (*Ley de Aguas de Propiedad Nacional*) allowed users to pump groundwater in their fields as long as this activity did not affect 'national' water bodies (Dominguez and Carrillo-Rivera 2007). If this were the case, the state would have the power to stop such activities. The Law's subsequent regulation further increased the control of the state as it established the need to request a permit in order to recognize the right to abstract groundwater in the case the abstraction would be interfering with water resources declared as national or in the areas where groundwater abstraction has been limited (*zonas de veda*).[172] A further regulation of groundwater came in 1948 as part of the revision of Article 27 of the country's national constitution of 1917 (Wolfe 2013).[173] Previously, the only

[172] Waters declared national were seas, and those water bodies and rivers communicating with the sea and constituting borders between territories. Access to these waters was public and regulated (with priority to drinking water supply) (Dominguez and Carrillo-Rivera 2007).

[173] The first legislation aiming to regulate and manage water in Mexico was issued in 1910. This legislation considered only surface water as a public domain and did not make any reference to groundwater (Dominguez and Carrillo-Rivera 2007).

reference to groundwater in Mexico was the 1884 Civil Code which granted the right to drill wells or build diversion dams to capture water to land owners within their land plot (ibid.).

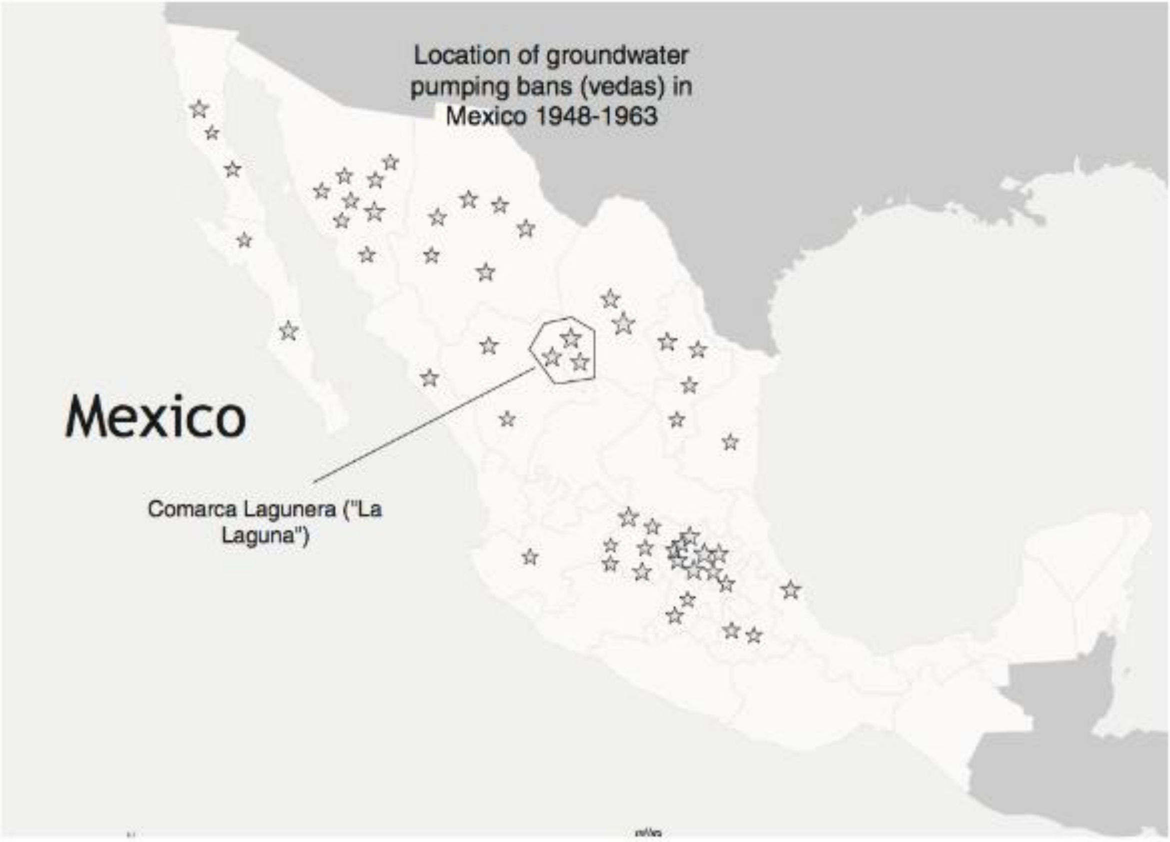
The reform introduced in 1948 aimed at completing what had been stated in the 1917 Constitution, i.e. the nationalization of Mexico's waters. The reform was also aimed at revising Article 27 of the Constitution, which "enshrined agrarian reform as a popular right born of revolutionary armed struggle" (Wolfe 2013: 10). The revision of Article 27 also introduced groundwater in the article, so it could be subject to federal regulation. Such revision stipulated that "although landowners may extract and consume groundwater through artificial works, the federal government could regulate that extraction if 'the public interest so requires or others' use is affected' by establishing prohibited areas" (Wolfe 2013: 10-11). The revision also contemplated penalties for the violation of the law and authorized the water authorities "to prevent the installation of works or technologies that could do so, even to the point of demolishing such works" (Wolfe 2013: 11). The regulation also required property owners to inform the water authority when initiating any work to extract groundwater (with the exception of wells for domestic use) (Wolfe 2013). The law also contemplated the use of pumping bans in specific aquifers following the depletion of the resource, salinization or impacts 'in the sub-soil' (Dominguez and Carrillo-Rivera 2007).

The 1948 reform was contradictory however as, according to Wolfe (2013: 34), it simultaneously empowered "the government to regulate groundwater through *vedas* (prohibition areas) and other command-and-control measures" but also promoted at the same time the use of groundwater for agricultural development through massive irrigation projects (e.g. the Nazas River basin watering the Laguna region in Central Mexico) (Wolfe 2013). Business interests and political maneuvers fueled the development of groundwater via the introduction of pumping technology from the United States by former ministerial officials with a commercial interest in the venture (ibid.). The use of pumping bans has been used in Mexico since 1948 as an attempt to regulate groundwater abstraction (50 *vedas* established between 1948 and 1963) (Figure 78). Groundwater abstraction had in some places already reached unsustainable levels as early as the 1930s, and some engineers and officials from the Ministry emphasized the need to regulate groundwater and recommending federal jurisdiction over and regulation of the resource.[174] The enforcement of these vedas was however poor, as the water authority did not monitor groundwater withdrawals from individual wells. The lack of awareness about the law, the negligence of groundwater users, and their noncompliance of the law also added to the lack of enforcement (ibid.).

Even though the existence of these vedas can be for perpetuity, groundwater users have found a way to bypass them and obtain new groundwater abstraction licenses. In the state of Jalisco for instance, politically connected well owners can obtain new concessions despite the general ban (World Bank 2009). The lack of political will and corruption of local government officials, and the distance from the capital play against the enforcement of regulations (ibid.).

[174] As studied by Wolfe, the concern of some engineers for the quick depletion of groundwater levels can be exemplified by the area of La Laguna, where the observation on dropping water tables corresponded with the installation of up to 1,000 pumps by 1937 (Wolfe 2013). The abatement of the aquifer in 1932 and 1934, with marked decreases between 7 and 15 meters, and in 1935 a further drop between 15 and 20 meters had been noticed (ibid.). The Comarca Lagunera has 8 main aquifers with the major aquifer being a sedimentary alluvial aquifer made of Paleozoic rocks (Cruz and Levine 1998). The main aquifer has a surface area of 14,000 Km2 and an estimated abstraction of 746 Mm3 (1994 data), 71 percent of which is for agriculture (ibid.). Recorded groundwater static levels in 1945 indicate a groundwater depth of 45 meters and 61 meters in 1982 (ibid.).

Figure 78. Location of groundwater pumping bans in Mexico (1948-1963)



Source: Wolfe 2013.

In 1992, a new National Water Law in Mexico included as part of the public domain, both surface and groundwater, and expressed the necessity for all groundwater users to register all groundwater abstraction points in the Public Registry of Water Rights, granting them the right to abstract a certain amount of groundwater for each well (called a 'concession')[175] (CONAGUA 2009). The National Water Commission (CONAGUA) (the country's national water authority) estimated in 2009 that there were around 140,000 wells in the country, 42,600 of which were officially registered and another 10,000 had some kind of authorization (Figure 79) (ibid.). The procedure for regulation was opened in 1995 and ended in 1999 (ibid.). The multitude of 'irregular' or provisional extraction authorizations needed to be regularized and added to the Registry of Water Rights but due to insufficient institutional and human resources, the water administration could not verify the authenticity of the permits or confirm the legitimate use of groundwater (World Bank 2009). The result was that many farmers were granted legal rights to much more water than can be sustainably abstracted (ibid.).

A final legal reform came in 2004 with the latest National Water Law in Mexico (Dominguez and Carrillo-Rivera 2007). This law integrated water resources management under the Commission Nacional del Agua as well and created river basin agencies to manage the resource (ibid.). The 2004 Water Law also codified in an article the already existing COTAS (*Comites Tecnicos de Aguas del Subsuelo o Subterraneas*), established since 1995 in order to manage groundwater

[175] Concessions would be calculated by CONAGUA according to the groundwater needs of the user and the availability and state of groundwater resources in the aquifer. In many instances, farmers are not even aware of their official concession volumes (World Bank 2009).

resources (ibid.).[176] The COTAS are administrative units that support the River Basin Committees so that they can coordinate and better integrate the participation of all groundwater users within a basin (ibid.).

The lack of effective regulation in Mexico despite several attempts by CONAGUA (National Water Commission) in 2011 and 2012 to close down wells without a license in 5 different regions (achieving a 10 percent rate of success), has created country-level over-abstraction of its aquifers, with 101 out of 653 declared overdrawn (Figure 79 and Figure 80) (Muñoz-Piña n.a.; OECD 2013). Additionally, the water authority lacks personnel to control abstracted volumes or the drilling and exploitation of illegal wells (OECD 2013). According to the World Bank's (2009) Poverty and Social Impact Analysis of Mexico's groundwater over-exploitation, the number of groundwater users controlled in 2004 was only about 1 percent of those registered in the Public Registry.

Instances of corruption within the regulatory system of water management are also found in Mexico. In the irrigation sector these corruption cases are related to capital-intensive investments and also to groundwater regulation. Falsified well and concession registrations and permits are common (it is estimated that in the Valley of Mexico there is one unregistered well for each official well permit) (OECD 2013).

A further regulation derived from the Water Law also demands groundwater users to install water meters in their wells, with administrative and financial sanctions for non-compliance (ibid.).[177] The system of sanctions is however perceived by users as ineffective, as extremely high fines for violating concessions limits are sometimes imposed but are also criticized as unfair and unrealistic by users (ibid.). Monitoring is also difficult due to inaccuracies of official statistics quantifying the area irrigated with groundwater. As an example, official statistics for the state of Guanajuato show that there are 250,000 hectares irrigated with wells. However, alternative methods used by the Secretariat for Agriculture (aerial photography and on-site visits) have quantified the irrigated area at around 326,000 hectares (ibid.). The agency also concluded that despite the official number of registered wells being 13,500, the real number of wells is closer to 18,000 (ibid.).

3 Illegal water markets[178]

A system of concessions was introduced in 1992, and between 1993 and 2000 all water uses in prohibition zones were to be regularized as concessions (use right of usually 10 years). In Toluca Valley in central Mexico (Reis 2014), to establish volumetric concessions, officers used information such as the characteristics of the construction and operation of the well, the number of hectares irrigated (assigning for example 6,000 m3/year/ha), etc. But it also surfaced that agricultural users could state any volume they wanted during regularization and would get the concession; as a result most agricultural users are over-allocated or "over-concessioned", having concessions for higher volumes than they actually use. There is great uncertainty regarding actual water extractions by farmers, because agricultural wells do not have meters

[176] See Section 3. Until 2004 there was no specific mention of COTAS in Mexico's water law, making their legal and administrative status ambiguous, mandate, and structure (Wester et al. 2011).

[177] Fieldwork conducted in 6 aquifers by the authors of the Poverty and Social Impact Analysis for the World Bank in Mexico revealed that installed meters are frequently in disrepair and that CONAGUA officials are keenly aware of these monitoring problems (World Bank 2009).

[178] This section draws on Reis (2014).

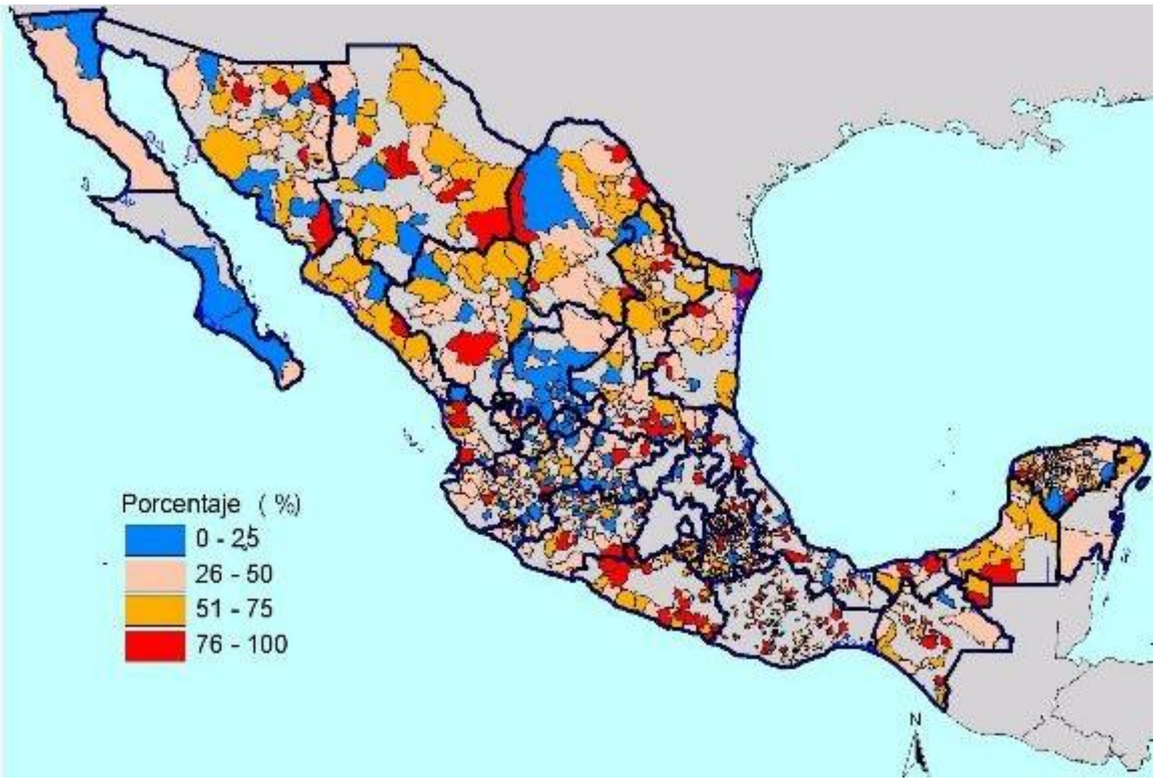
and surveillance by CONAGUA is weak to nil. Farmers do not pay for water but industrial users do, are metered and monitored, since they generate revenue for the administration.

The main demand for groundwater came from housing construction companies due to the boom of real-estate development. Intermediaries named *coyote* mediate the cession of rights by farmers to the benefit of those companies through the administration. Payments to coyotes as well as bribing of officials to oil the transfer are formally illegal since water belongs to the state.

To potentially reduce the amount of water abstracted, one would need a strict monitoring of actual uses. But a large part of water extraction in the Valley of Toluca is not metered and/or thorough surveillance of water extraction, notably by farmers, is deficient. Industrials also know how to stay 'in good terms' with the administration (CONAGUA), in order to incite their leniency when reading meters. Furthermore farmers are allowed to transfer/sell part of their concessions, but in practice continue to use the same volume, which increases abstraction.

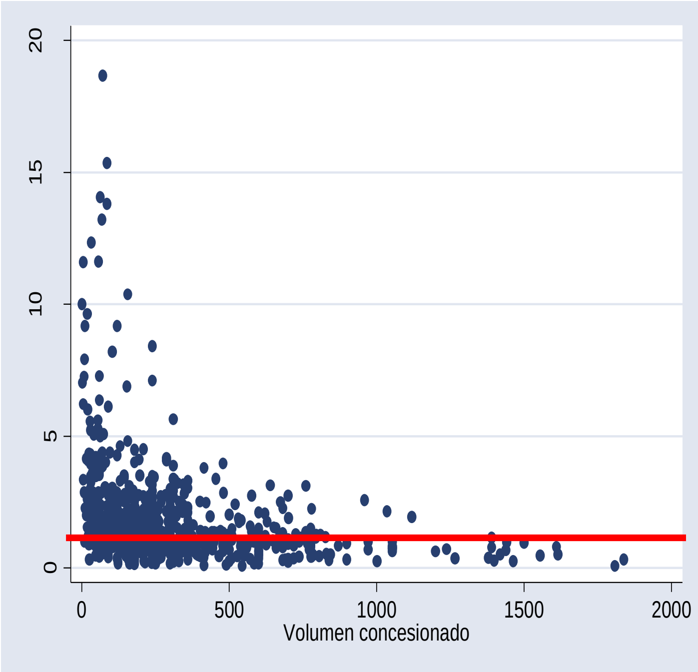
This suggests that the illegal market has consolidated itself as a structure possessing its own dynamics and emerging properties. The creation of an (illegal) water rights market was an unintended consequence of the policy reform of the 1990s, which sought to cap water use abstraction by defining/limiting authorization to use water (concessions) in prohibition zones (*vedas*). It now has powerful interests associated with it, since 'trading' generates important financial benefits to powerful people as well as to the administration. Likewise industrial users have used lawyers to successfully challenge the *caducidad* system, which was supposed to cancel rights that were not put to use (either reserved for future development or for speculation).

Figure 79. Percentage of estimated illegal groundwater users (2008)



Note: Map shows percentage estimates at the municipality level.
Source: Muñoz-Piña (n.a.).

Figure 80. Ration between current groundwater abstracted volume and authorized volume in Mexico



Note: the red line indicates approximately a ratio of 1 (= groundwater users are abstracting what their permit allows them to abstract). Anything above the red line indicates the non-compliance with the law).
Source: Avila et al. 2005.

4 Reducing/buying back water entitlements

Another example of market mechanisms in Mexico is provided by the case of the Altar Pitiquito irrigation district (ID037), in the state of Sonora, which was created in 1949 with an irrigable area of about 60,000 ha served by the water extracted by 844 wells (Ojeda-Bustamante et al. 2015). At its peak 55,000 ha came to be irrigated with a groundwater volume of 760 Mm3, figures which, because of over-pumping, dropped and have now more or less stabilized at about 20,000 ha for 795 pumping wells distributing around 300 Mm3. It must be noted that over-exploitation has been recognized as early as 1963, and then 1978 when the drilling of new wells was prohibited by a presidential decree establishing a prohibition zone (Cáñez Navarrete n.d.). Pumping levels vary from 150 m to 120 m (with a continuous drop of around one meter per year), which means that pumping costs are quite high and are therefore associated with cash crops (mostly fruit trees and asparagus) irrigated by micro-sprinkler or drip irrigation systems for 80 percent of the area (ibid.) (Reyes Martínez and Quintero Soto 2009).

After transfer of management responsibilities to farmers in 1994 in the Altar-Pitiquito-Caborca irrigation district, water users immediately defined and imposed a water reduction program upon themselves, with a gradual reduction in the volume of each well during ten years, in order to reach the figure of 300 Mm3, (wrongly) considered as the safe yield (Table 13; Wilder 2002). The water reduction plan and retiring of wells have proved insufficient to halt the serious groundwater depletion.

Table 13. Plan of reduction of abstraction adopted by the WUA

Agricultural cycle	6'' Well (Mm3)	8'' Well (Mm3)	10'' and 12'' Wells (Mm3)	Total volume (Mm3)
1994-1995	385	683	1,069	755,761
1995-1996	366	651	1,019	720,291
1996-1997	336	599	937	662,651
1997-1998	303	539	843	596,335
1998-1999	272	484	759	536,614
1999-2000	245	436	683	483,043
2000-2001	221	393	615	434,705
2001-2002	199	353	553	391,214
2002-2003	179	318	498	352.116
2003-2004	161	286	448	317,910
2004-2005	153	272	426	300,992

Source: ASUDIR.

In 2003, as part of the Water Rights Use Adequacy program (PADUA) (2003-2006), which sought to reduce over-allocation of water in Mexico by paying back water rights, 30 pumping wells were cancelled. On average water was purchased back at the price of USD 243/1000 m3, a price that was largely unconvincing for most farmers because of the high economic return of this intensive agriculture. It is proposed to equip all wells with meters, and to cancel out 329 wells to leave only 501, in order to achieve a better balance between use and available resource. Aquifer recharge (natural and induced) was estimated at about 300 Mm3 in the 1970s and later at 213 Mm3, with an annual water extraction at about 308 Mm3, leaving a deficit of 94.7 Mm3. More recently recharge was estimated at 118 Mm3 only, indicating that over-exploitation is much higher than believed. Extraction is estimated based on the observation of the static level in a winter month with no use. Volumetric monitoring of use is still partial: in 2003, only half of the wells were equipped with meters, and normally 81 percent of those were functioning (Reyes Martínez and Quintero Soto 2009). Consequently, water abstraction is assessed based on electricity consumption.

5 Energy and groundwater nexus in Mexico

In Mexico, artificially low electricity power fees with subsidies create an incentive for greater resource abstraction for farmers even when they do not reach the abstraction quotas mandated by the state, causing an artificial profit for certain crops (OECD 2013; Muñoz Piña et al. 2006; Wester et al. 2009). Electricity used in agriculture (mainly used for pumping groundwater from wells) benefits from a special tariff benefiting farmers as they only pay 23 percent of the actual cost of electricity (OECD 2013). The beneficiaries of these subsidies are however well-off farmers most of the time as they are the ones able to invest in expensive pumps and deep boreholes (OECD 2013). Poor farmers typically use shallow wells with traditional water lifting devices (i.e. water wheels) or surface water instead (ibid.). Moreover, a special 'night-time stimulus tariff' applied for pumping between midnight and 8 AM introduced in 2003 caused further increases in groundwater withdrawals as farmers over-pumped at night in order to benefit from the reduced night tariff (the average day-time tariff is USD 0.048 KW per hour compared to USD 0.039 kW per hour at night, around 20 percent below day-time tariffs) (Scott 2013; Scott and Shah 2004). Night time irrigation also often involves further costs to construct reservoirs to store the pumped groundwater until farm labor is available the following day. This can also require, according to Scott (2013,) further pumping to pressurize irrigation equipment (e.g. drip irrigation).

In the Altar-Pitiquito district, Sonora, the electricity required to run deep well pumps is a major costs for producers in the scheme. Water costs alone increased by 89 percent for wheat, 118 percent for table grapes, and 186 percent for asparagus in the first six years after the transfer of management to WUAs in 1994 (Wilder and Romero Lankao 2006). Electrical energy consumption accounts for 30 percent of total production costs on average, and small producers are frequently unable to pay their high electrical bills. Such default in payment results in power being cut-off within ten days, something which happened to half of the water users (Wilder 2008).

Costs increase and well outflow decrease with the drop in the water table (a well that could irrigate 100 ha in the past now can only irrigate 40 hectares), the depth of the well, the (lack of) repair of the pump/engine, inefficient pumps (water utilization is measured by electrical consumption, therefore new/efficient engines are at an advantage), reduced energy subsidies: in other words, these difficulties gradually displace small farmers and rich investors get the upper hand: eighty-six percent of the wells in the Caborca irrigation district are now owned by the private sector (with 80 percent of the asparagus area farmed by foreign companies). People leave agriculture because of debts, unpaid electricity bills that result in power being cut off, dwindling water and increased production costs, lack of interest in farming, turning to other activities (including drug trafficking), one-off attractiveness of getting money for selling water rights (or land), or leasing it out (Wilder 2008).

6 User participation and groundwater management in Mexico

In Mexico, the experience with water user communities started after the 1980s with the emergence of multi-stakeholder platforms pushed forward by the federal government, after more than 100 years of centralizing policies, and the creation of new water management coordination bodies such as River Basin Councils and technical committees for groundwater management, or COTAs (Marañon Pimentel 2010; Wester et al. 2007). In spite of such good political will, conflicts have arisen around the allocation of water in some of these basins. In the Lerma-Chapala Basin for instance, representing 9 percent of Mexico's GNP, the river basin council provides a forum for stakeholders to vent their frustration with the federal government's unilateral decision making, but is incapable of dealing with the legacy of the bureaucratic Mexican state (Wester et al. 2007). This situation complicates the administrative and political transition from a centralized system of water resource management to one of power and managerial devolution and decentralization (ibid.).

Following previous unsuccessful experiences, and in view of the continuous depletion of groundwater, the National Water Commission in Mexico started promoting the formation of COTAS in 1995 to organize aquifer users so that they could establish mutual agreements for reversing groundwater depletion in selected aquifers of the Lerma-Chapala basin (Perez Fuentes 2010; Wester et al. 2007). So far, 82 COTAS have been created at the aquifer level with the officially stated objective of restoring and protecting groundwater bodies and reach a balance between extractions and recharge (OECD 2013). These COTAS are inserted in the River Basin Councils (*Consejos de Cuencas*) since the 2004 reform of the Water law. These councils are a body set up with the executive but with limited representation from users, as their participation results from an invitation from the CONAGUA (if deemed necessary) (Valdes Barrera 2014).

As Wester et al. (2007) and Marañon Pimentel (2010) write, on paper the COTAS are participatory platforms where the users of an aquifer meet to agree on issues pertaining to aquifer management. The development of such platforms has been slow however due to unreliable information on pump owners and the lack of infrastructure and human resources on the part of the COTAS (Wester et al. 2007). The initial effectiveness of the COTAS to reach an agreement on reduction in groundwater extractions was undermined by this lack of resources, which caused that only a small group of community representatives were invited to participate (commercial farmers and agro-industrialists). As a result no mechanism to significantly reduce groundwater abstractions was agreed upon (Perez Fuentes 2010; Wester et al. 2007). Additionally, even though COTAS were created so that user participation could be improved, they retained a consultative role and did not create the necessary space to make decisions and devolve powers to the users (Castellan 2000 in Valdes Barrera 2014). Moreover, the Basin Council does not attribute any formal decision power to the COTAS, considered by the water law as a mere instance of consultation and coordination of policies but without authority (Valdes Barrera 2014).

The lack of sense of ownership of the COTAS amongst water users proved to be an obstacle for their consolidation as without proper representation of all groundwater users, no consensus on groundwater abstraction reductions was possible (Wester et al. 2011). This lack of representation due to a poor democratic process of selection and representation within the COTAS (Valdes Barrera 2014) also created the perception amongst users that COTAS mere just an extension of the state government in the form of an 'appendix' organization (Wester et al. 2011). The COTAS are also restrained by the overruling power of other government agencies and have no faculties to control groundwater abstractions, having to rely on the users' goodwill and on the National Water Commission, the only government agency with the powers to issue pumping permits and responsible for the enforcement of aquifer regulations (Perez Fuentes 2010; Wester et al. 2007).

In order to understand the process and problems of multi-stakeholder participation in Mexico it is important to understand institutional practices and their historical evolution (Marañon Pimentel 2010). The grip of the state on participative processes is still pervasive and in many instances the effectiveness of these processes is dependent on government intervention. The legacy of Mexico's highly centralized and bureaucratic state makes it difficult for regional and local agencies to play the role of facilitator and enforcer of rules. This is because decision-making processes at the basin level are still politicized and dominated by unilateral actions from the federal water agency (Marañon Pimentel 2010; Wester et al. 2007). As these authors reflect, the democratization process that has been taking place in water management in Mexico, which reflects wider changes in Mexican society, is a fragile process that can be easily derailed by interest groups and politics blocking the aspirations of water users to negotiate agreements with the centre (Wester et al. 2007).

The study of COTAS in other areas of Mexico such as in Guanajuato, Central Mexico (Figure 76), highlighted further implementation and design flaws (Caldera-Ortega 2013; Wester et al. 2011) despite having created them, as the OECD (2013) states, as 'councils' (*consejos*) instead of the traditional COTAS in the rest of the country. According to the OECD (2013: 131) the structure of these councils has "brought progress to the region's management of aquifers" despite lacking in legitimacy and recognition of their work. The constitution of the COTAS included representatives of the agriculture sector (mostly commercial farmers) but no members of the peasant sector. Agriculture represented around 80 percent of water use in Guanajuato but only had one representative out of a total of four on the board (along with one for industrial, one for drinking water and another from the service sector) (Caldera-Ortega 2013; Perez Fuentes 2010). The call for elections was restricted to relevant regional figures and powerful members of local communities (Perez Fuentes 2010). Moreover, as Caldera-Ortega (2013) has studied in Leon, the capital of the state of Guanajuato, the influence and power of specific policy networks, oriented towards the representation of strong local business interests (tanning and shoe making industries) ensured the control of water management policies by these groups (Caldera-Ortega 2013). These groups managed to position themselves as the main political group in the municipality and since the 1980s and 1990s they managed to place many of its members in the 'high spheres' of politics at the state level (due to their links and membership to the ruling party 'Partido Accion Nacional' – PAN) (ibid.). These same local elites managed to take over most of the managerial positions in the water management agency (the 'Junta de Administracion del Agua') in 1982 and the Wastewater and drinking water company in Leon (the ’sistema de Agua Potable y Alcantarillado' – SAPAL) in 1984 (ibid.).

The creation of COTAS in Leon and Guanajuato did not represent a substantial increase in stakeholder participation but, rather, the formalization of previously existing links between water agencies at the federal and state level and organized user groups, who often would benefit from state and federal programs (such as the use of improved technology to increase water efficiency) (Caldera-Ortega 2013; Maranon Pimentel 2010). The representation of these groups became another instance to formally co-opt more instances of power within these institutions. Their representation in the Basin Committee was also a way to leverage power and ensure that their interests were protected (e.g. demanding more water for the region through water transfers) (Caldera Ortega 2013). User participation remained merely 'consultative' without co-responsibility in management decisions (Perez Fuentes 2010). The institutional framework set up with the COTAS did not include the users most responsible for the depletion of the aquifers (which was also the majority of small farmers producing alfalfa, maize, and other fodder crops) due to their number and the fact that it was a very top-down process (Caldera-Ortega 2013). At a national level, the National Water Law did not define clear roles and prerogatives for the COTAS, leaving users with "subjective responsibilities to sustainably manage water in a context of already limited citizen participation" (OECD 2013: 117). The lack of representation of users in the COTAS was also due to political pressures and rushed timelines. In Guanajuato State, the Water Commission wanted to constitute the COTAS before the presidential elections of 2000, thus inviting leaders of diverse organizations and commercial farmers and agro-industrialists (Wester et al. 2009).[179] The COTAS also lack human expertise to deal with technical issues and in general there is a lack of hydrogeological data to make informed decisions (OECD 2013).

Following Valdes Barrera (2014) and his study of the COTAS in the Guadalupe Valley (Lower California), the COTAS depend financially on the CONAGUA. They are subject to its mandate and whatever the CONAGUA considers necessary and relevant in terms of management objectives and regulation. Sometimes the COTAS are not invited to the coordination meetings by the CONAGUA (or invited late), and are relegated to attending the regular meetings at the Basin Commission (ibid.). Members from this COTAS also received poor training and never on methods to improve the participation of groundwater users in the COTAS. The lack of trust and interest from users (as they do not see the benefits of the COTAS tasks and missions)

[179] Agriculture is also under-represented in the COTA. Even though it uses around 80 percent of groundwater, it only has 25 percent of the weight in the COTAS board (Wester et al. 2009).

undermines their role within the community (only 10 percent of users attend the meetings and assemblies) (ibid.). This lack of attendance and trust is also driven by the perception amongst users that the COTAS are in place to denounce illegal wells and abstractions.

In general, the analysis made by Wester et al. (2011) on the poor success of the various attempts to regulate groundwater over-abstraction in Mexico emphasizes that the government was insensitive to economic and social drivers influencing groundwater over-abstraction. Moreover, the government assumed that the problem was that groundwater users were not sufficiently informed to be able to define common mechanisms and agreements to reduce groundwater use. Thus, in spite of the state trying to create the right organizational environment and provide users with information, farmers' rationale did not meet the government's expectations: as a farmer said "we are not groundwater managers, we are agricultural producers; water management is the responsibility of the state" (Wester et al. 2011: 896). Also, due to the informality of most irrigation schemes (not formally regulated), this same lack of official institutionalization restricts the participation of users and their integration into the COTAS (OECD 2013). Moreover, the strong resistance from the federal state to decentralize appropriate decision-making powers, investment funds, and technical and managerial resources has contributed to the inability of COTAS (as well as of River Basin Councils) to effectively reduce groundwater over-abstraction due to their limited financial and managerial attributions (ibid.).

Research on user communities in Mexico also shows how the politicization of administrative and regulatory competencies can undermine the potential results of devolution to local communities of aquifer users. In Mexico, political struggles over water control between different administrative levels led to the polarization of efforts and inter-institutional struggles, instead of an integration and coordination of concerted efforts (Wester et al. 2009). Strong mandates for groundwater user associations with effective checks and balances are an important ingredient if they are to empower user communities and avoid the replication of power dynamics or the creation of new ones with no accountability to their constituents or the state (Wester et al. 2011).

Table 14. Comparison of user participation in 3 selected Mexican COTAS

Groundwater body (state)	Mechanisms of stakeholder participation	Achievements	Limits
Santo Domingo aquifer	COTAS was formed following unenforceable federal regulations, larger farmers bought-out small farmers and invested in modernising irrigation technology	– More than 60% reduction in groundwater abstraction between 1995 and 2006 – Groundwater abstraction metering installed and maintained with monitoring of groundwater levels and quality – Full agreement on future groundwater and soil conservation measures	Concerns about socio-economic consequences of displacement of smaller farmers
San Luis Potosi Valley aquifer	COTAS was formed by private users, municipal water-supply utility and state government. Surface water dam and reservoir were also built to reduce groundwater dependency	– Good co-operation with full water-well inventory, users directory and well metering – Participatory drafting of regulations to stabilise aquifer and reserve good-quality groundwater for potable supplies	Uncertain federal endorsement and financial support to implement the aquifer stabilisation plan
Silao-Romita aquifer	Since 1998, the state government has strongly supported cross-sector groundwater management associations such as COTAS and has promoted aquifer management actions	– COTAS raised awareness leading to watershed conservation programmes – Numerous aquifer models prepared by the State Water Commission – Elaboration of aquifer stabilisation plans at the federal level	– Water-well drilling bans have been ineffective due to poor enforcement – COTAS have not been able to mobilise effective action to reduce net abstraction and stabilise aquifer water levels – Inadequate devolution of resource administration from federal level to state and COTAS

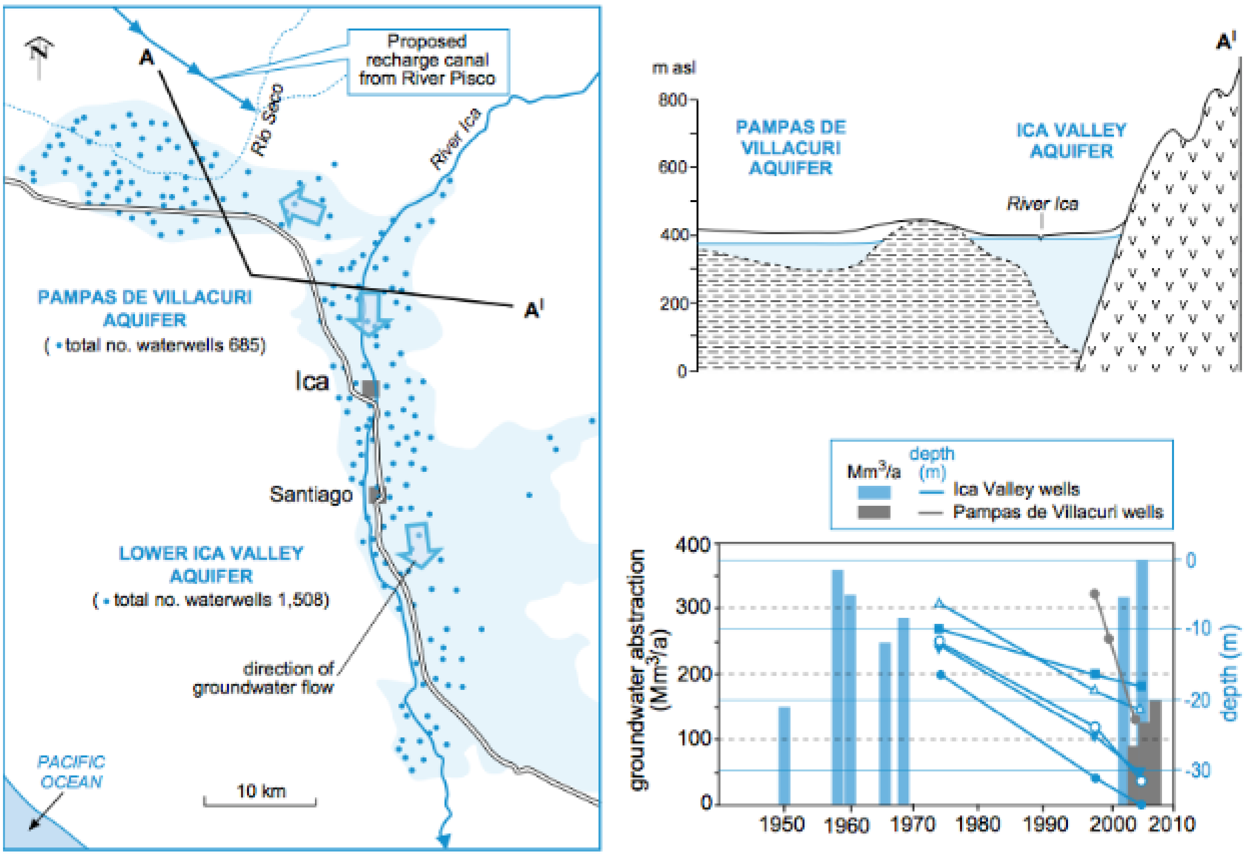
Source: OECD 2013.

Part 2. Groundwater development and over-abstraction in the Ica Valley, Peru

1 Groundwater resources and management in the Ica valley

The Ica-Pampas de Villacuri aquifer system in Peru is the largest in the country and represents between 30 and 40 percent of the total volume of groundwater abstracted nationally (ANA 2010; Oré et al. 2012; Oré et al. 2013). It is found in the hyper-arid Ica valley around 300 kilometers south of Lima, where the average rainfall is less than 50 mm per year. The aquifer can be divided into two sub-aquifer units, the Lower Ica aquifer (a quaternary alluvial aquifer with up to 200 meters of saturated thickness, between 10 and 60 meters deep) receiving continuous recharge from the Ica River (Figure 81) (Garduño and Foster 2010). The second sub-aquifer unit, the Pampas de Villacuri aquifer, consists of alluvial deposits with very occasional recharge making it an effectively non-renewable groundwater source (ibid.). Groundwater accounts for sixty five percent of the total water demand for agriculture in the Ica Valley and since the end of 2010 the Ica Valley is in a situation of dire emergency due to groundwater over-abstraction.

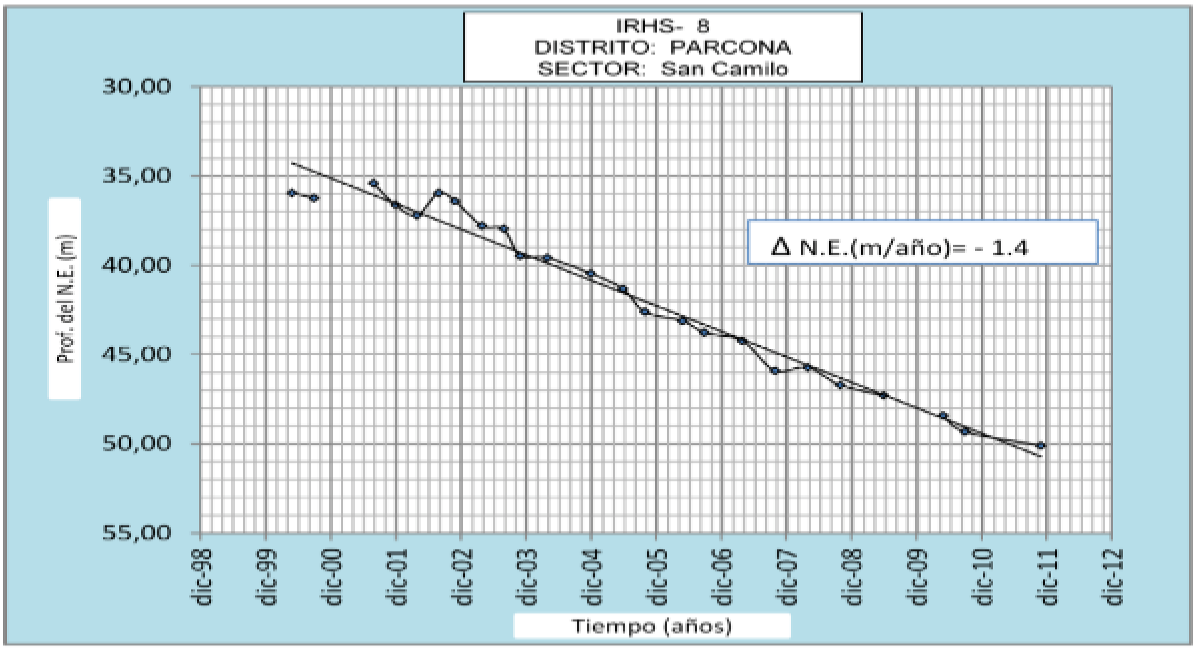
Figure 81. The Ica valley, Peru



Source: Garduño and Foster 2010.

Groundwater abstraction in the Ica valley represents a total of 545 Mm3 per year, of which agriculture takes 513 Mm3 (Ministerio de Agricultura 2010a). In terms of over-abstraction, groundwater reserves in the Ica valley are currently exploited at 76 percent over the sustainable yield for the Ica sub-aquifer unit, and 262 percent for the Villacuri sub-aquifer unit, leading to important water table drops (1.4 meters per year between 1998 and 2011 in the Ica sub-aquifer and 1.5 meters per year for the Villacuri sub-aquifer) (Figure 82) (Ministerio de Agricultura 2012). This over-abstraction of groundwater at increasingly deeper levels has also led to an increase in salinity (as groundwater at deeper levels is increasingly saline), with recorded levels increasing from 0.5 mmhos/cm to 0.84 in the Ica sub-aquifer and from 1 to 3.8 mmhos/cm in the Villacuri sub-aquifer (ibid.).

Figure 82. Water table levels in the Ica sub-aquifer

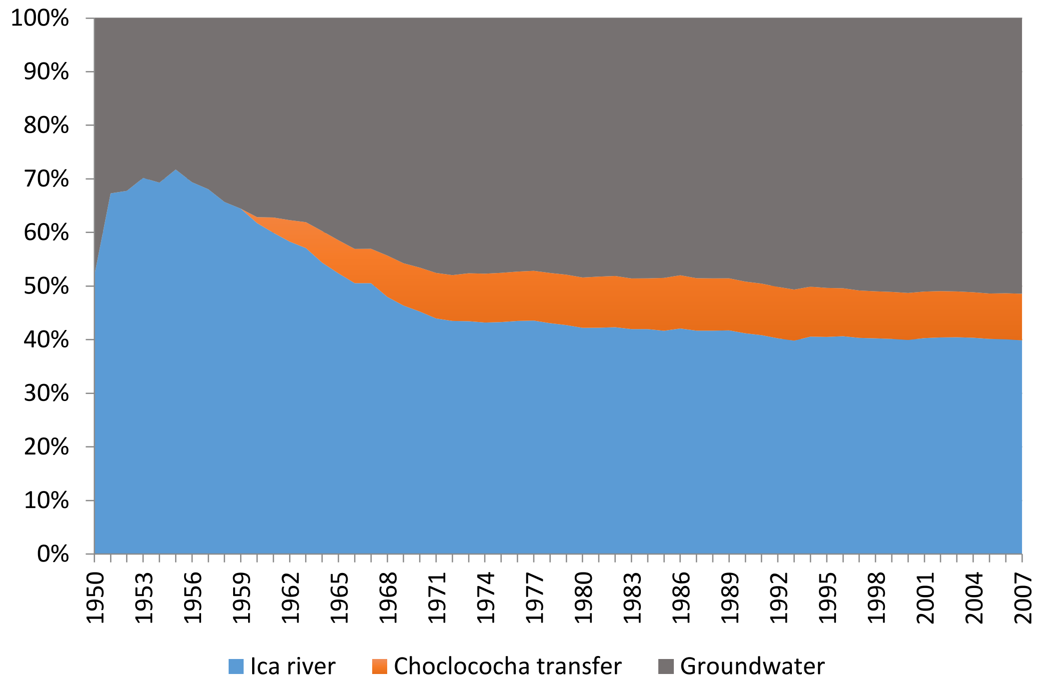


Source: Ministry of Agriculture 2012.

The development of agriculture based on the Ica aquifer started in the 1950s due to the availability of groundwater, which sustained the development of cotton farms and grapes (ibid.) (Figure 83).[180] Additionally, in 1959 the Choclococha project was designed and built to transfer surface water from the Choclococha basin to the Ica valley. In 2002 it transferred 225 Mm3 per year of surface water to the valley (Ministerio de Agricultura 2012). Increase in groundwater abstraction in the 1990s followed as new crops were introduced in the valley such as asparagus, paprika, grapes, and mangos. Intensive agriculture turned Peru in one of the major exporters of some of these products (particularly asparagus where Peru is the second largest exporter behind China, harvesting them all year round) (Meade et al. 2010) (Figure 84). The increase in production of this type of crops was sustained by the development of new technology such as drip irrigation introduced by new national and international agri-businesses (Ore et al. 2012). The cultivated area with asparagus in the Ica valley reached 10,400 hectares in 2011 (from 411 in the 1991) and 5,040 hectares for grapes (Ministerio de Agricultura 2012). The Ica Valley was already the main agro-exporter in Peru in the mid-2000s, representing almost 30 percent of the horticultural and fruit exports of the country (Rendon Schneir 2011).

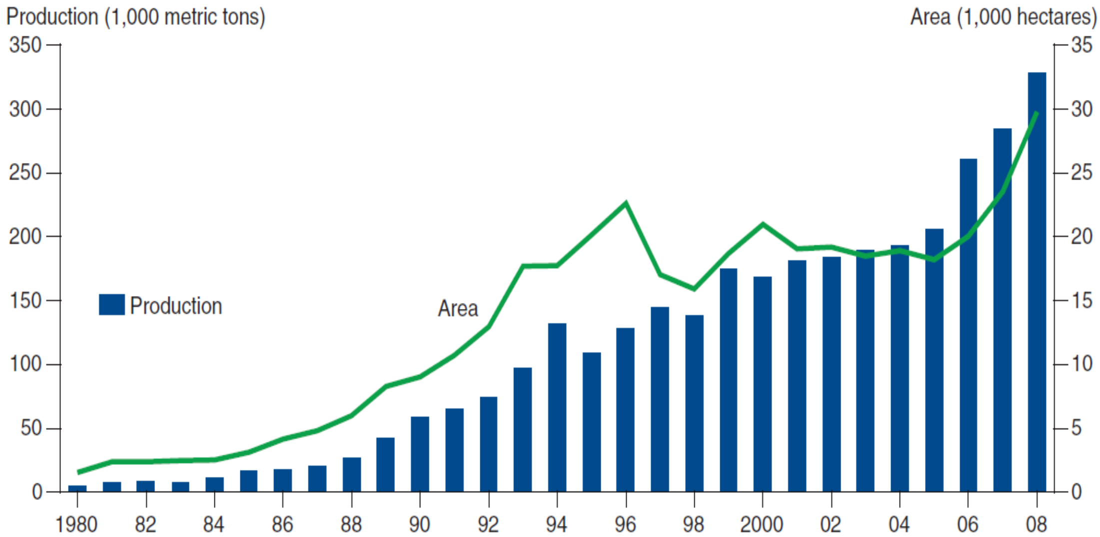
[180] The transition from cotton to other crops happened during the 1960s when the USA liberalized the commercialization of its cotton exports, producing a drop of the price of this community worldwide. In the 1970s and 1980s, Peru restructured its agricultural sector and expanded the production of other crops (such as asparagus) (Rendon Schneir 2009). Nevertheless, in 2008 cotton continued to be planted and harvested in the Ica valley (with 6,910 ha cultivated, the second crop behind asparagus) (ibid.).

Figure 83. Evolution of water supply in the Ica valley according to sources (in percentage)



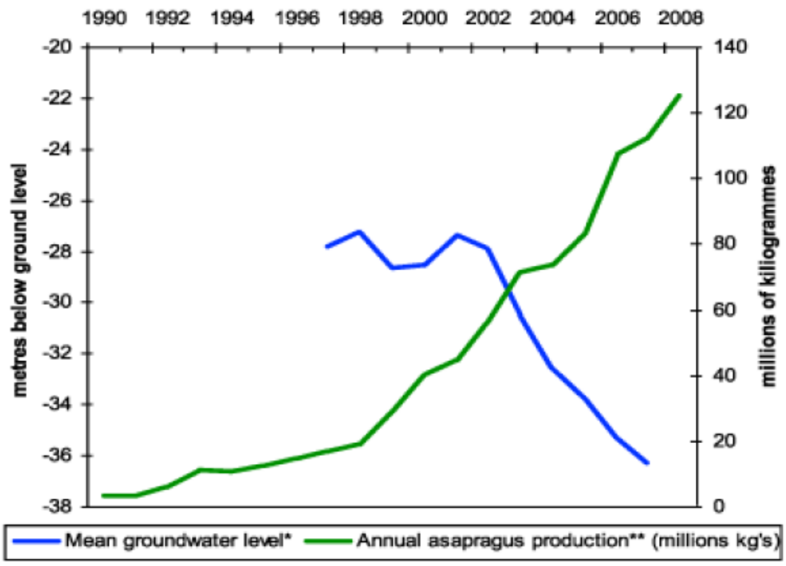
Source: Based on data from Rendon Schneir 2009.

Figure 84. Production of Peruvian asparagus between 1980 and 2008



Source: Meade et al. 2010.

Figure 85. Asparagus production and groundwater levels in the Ica Valley between 1990 and 2008



Source: Hepworth et al. 2010.

2 Weaknesses of groundwater regulation in the Ica valley

Water resources in Peru are managed by the Ministry of Agriculture and Irrigation. The National Water Authority (*Autoridad Nacional del Agua*) was set up in 2008 acting as the regulator for water management and depending on the Ministry of Agriculture and Irrigation.[181] This represented a problem according to Lynch (2013) as the ANA is located within the Ministry of Agriculture and therefore prone to subordination to agribusiness interests and dominated by irrigation engineers.[182] Peru's 2009 water law replaced the 1969 old water law, aiming for the sustainable utilization of the country's water resources. In the Ica valley, Peru's water authority inventoried 1,700 wells in the Ica valley of which 451 have a license (Ministerio de Agricultura 2012). In the Ica sub-aquifer, 71 percent of all wells inventoried have no license, like 70 percent of the wells in the Villacuri sub-aquifer (ibid.).

In 2008 the government of Peru declared a ban on groundwater rights for the Ica-Villacuri aquifer (*zona de veda*), ratified in 2009 and 2011 (as part of the regulatory powers of the National Water Agency). The last ratification in 2011 included, apart from maintaining the ban for groundwater abstraction rights, the installation of meters for wells, control and monitoring of aquifer levels with the participation of user groups. Despite these measures, groundwater abstraction levels have increased, and so has the irrigated area in the Ica valley and the number of wells without authorization.

[181] Following Lynch (2013), the creation of the ANA in 2008 was a result of the country's renewed efforts at water reform with loans and technical assistance from the World Bank and the Inter-American Development Bank. The Water resources modernization project embraced Integrated Water Resources Management (IWRM) and as a consequence, all water regulatory and management aspects at the central government level were integrated under a single agency: ANA.

[182] The lack of competencies of ANA extended to an absence of crop engineers meaning that the agency lacks the ability to evaluate agronomic water demands. It also lacked of water quality experts. It had also outsourced to the Ministry of Mines the environmental impact assessments of mining operations in the country (being transferred to the Ministry of Environment in 2013). The agency also lacks instruments for ecosystem protection (Lynch 2013).

The Environmental Impact Assessment (EIA) issued by the *Contraloria General de la Republica* (the main body overseeing the application of public policies in Peru) in 2011 presented a list of observations regarding the activities of the ANA in the Ica valley (Contraloria General de la Republica 2011). Despite having issued numerous censuses and studies of the availability of groundwater in the Ica Valley, the ANA had not determined the values of groundwater supply and demand for the valley in order to update the maximum annual groundwater volume to be abstracted from the aquifer. Moreover, the ANA had not been registering nor maintaining updated information on the well permits granted in the valley for agriculture (with 127 resolutions issued between 2009 and 2011 pending to be registered and updated in the data base). The granting of licenses for agriculture has been done without a serious or real oversight and control of the flows abstracted by the wells and the type of abstraction regime done by the users. Additionally, during the period 2009-2011, 81 percent of authorized wells did not have a meter installed and no regular control or checks were being done on the monthly reports submitted with meter measurements, nor any sanctions issued.

The National Water Authority therefore developed a Groundwater Management Plan for the Valley (Ministerio de Agricultura 2012) aiming to inform and raise awareness about the state of groundwater and the need to sustainably manage and preserve groundwater resources, as well as to train and improve institutional capacities and coordination (with a budget of 3.4 million USD) (ibid.). The plan also aims to improve data collection and the diffusion of information on the state of the resource (modeling, aquifer levels, recharge rates, abstraction levels) (ibid.). Some of the measures aiming to reduce groundwater abstraction levels put forward in the plan include:

- Crop substitution;
- Limiting groundwater abstraction levels in each of the sub-aquifers through abstraction licenses;
- Undertake a census of all the wells without licenses;
- Require the installation of water meters in all wells (with a deadline of 180 days established via Decree in 2011);
- Control the drilling of new wells via the registration of electricity permits (in coordination with the Electricity Agency as it had been suggested by the EIA and in application of the Supreme Decree 025-2007-AG issued in 2007) (ibid.);[183,184]
- Aquifer recharge is also envisaged, as well as continuing the supplement of surface water to the valley from other basins (ibid.).

[183] In 2007 the Supreme Decree 025-2007-AG declared that the applicants for an electric connection for groundwater wells would have to present to the utility a copy of the permit to abstract groundwater granted by the ANA. Gaceta Juridica, 2007, Year XXIV, Num. 9961, 352723, http://www.gacetajuridica.com.pe/servicios/normas_pdf2007/setiembre/07-09-2007/07-09-2007.pdf (Accessed 10th May 2015). However, the control of electric connections was not being enforced in the valley as mentioned by the Environmental Impact Assessment (EIA) for the Ica Valley and the Electricity Regulator had not initiated any sanctions against private companies supplying electricity to illegal wells. The assessment referred to the case of the electric utility Electro Dunas which had been supplying electricity to the agri-business company Campo Verde S.A. even though this company did not have a permit to abstract groundwater. The EIA recommended improving the supervision and oversight of these companies by the prosecutor in collaboration with the ANA (Contraloria General de la Republica 2011).

[184] In December 2012, the ANA issued an application process in order to a professional to undertake a technical feasibility study over 40 days to develop the control and inspection of wells in the Ica valley (including the control of electricity permits for illegal wells) (ANA, Adjudicacion de menor quantia Num.057-2012-ANA, Segunda convocatoria).

Further regulatory sanctions have been issued against large users in the Ica valley after the EIA was published. In May 2014 the National Water Agency issued a fine for an amount close to 130,000 USD to the company Agricola Miranda for having drilled wells within the banned area and proceeded to close the 10 wells irrigating 400 hectares. A representative of the farmers in Villacuri had reported the existence of such wells to the Water Agency[185] but when the Agency tried to control and monitor the wells by entering the farm, the company denied access.[186] The sanction was however issued by the Water Agency in May 2014 following the regulatory procedures stated in the Water Law. In the past two years the ANA has proceeded with registering water rights and there is yet no analysis of this on-going process.[187]

3 Land and groundwater management in the Ica valley

Land and groundwater in the Ica Valley are concentrated in a relatively small group of landowners. In 2012 there were 30 individuals owning farms between 80 and 2,000 hectares (Cardenas Panduro 2012). According to the same author, users in the valley exclusively abstracting groundwater represent only 0.1 percent of the total number of irrigators (ibid.). These groundwater irrigators accumulate nevertheless 23 Mm3 of water per year, the highest of all groups of irrigators (Ore et al. 2012). The large majority of farmers in the Ica Valley are however small farmers with less than 3 hectares (68 percent of the total number of farmers but own 12.3 percent of the land) whereas large farmers with 50 hectares or more represent 0.5 percent of the farmers but own 14 percent of the land) (Scamarone 2008).

In the 1990s the lack of well-defined land property rights resulted in 53 percent of farms not owning land property titles (Meade et al. 2010). President Alberto Fujimori wanted to solidify land property and enacted a series of decrees allowing the transfer of land titles to third parties and eliminated all acreage restrictions on landholdings (ibid.). The Titling Act from 1997 contained a further provision, which stated that uncultivated land would be declared abandoned by the state and publicly repossessed (Meade et al. 2010). This takeover benefited mainly large landowners who bought the land repossessed by the state, resulting in further concentration of land by a handful of firms producing crops predominantly for export (ibid.).

Groundwater accumulation processes by agri-businesses in the Ica Valley include legal and illegal strategies to secure access to the resource (Cardenas Panduro 2012). The allocation of groundwater abstraction rights is based on permits granted by the state. According to official records, groundwater users in the Ica Valley are allowed to abstract 111.4 Mm3 per year (in 2011), although the real volume of abstraction is estimated at 334 Mm3 (in 2009) (ibid.). This represents an illegal use three times larger than the publicly allocated abstraction volume by the state. Moreover, of all water rights granted by the Water Authority, 77 percent was for surface water against 23 percent for groundwater. Given that 65 percent of the water demand is covered by groundwater, there is an imbalance with regards to groundwater granted permits against demand, causing an imbalance in the hydrological cycle between surface and groundwater usage (ibid.). Recent data from 2014 on well inventories in Ica, Villacurí and

[185] Correo, "Denuncian 10 pozos illegales en agricola", 6th of November 2013, http://diariocorreo.pe/ciudad/denuncian-10-pozos-ilegales-en-agricola-69384/ (Accessed 18th November 2014).

[186] La Voz del Ica 2014 'Autoridad del Agua sanciona con 100 UIT a Agricola Miranda', 16th May 2014, http://www.cepes.org.pe/notiagro/node/21392 (Accessed 18th November 2014).

[187] http://www.ana.gob.pe/sala-de-prensa/noticias/noticias-2015/ana-orienta-a-m%C3%A1s-de-dos-mil-usuarios-de-ica-en-proceso-de-formalizaci%C3%B3n-o-regularizaci%C3%B3n-de-derechos-de-uso-de-agua.aspx

Lanchas by local water authorities (Aldoradín 2015) showed that only 21 percent of the wells identified were considered as legal (Table 15).

Table 15. Inventory of wells in Ica, 2014

Sector	Total number of wells	Being used	With license
Villacurí	1,169	474	127
Lanchas	1,087	444	78
Ica	2,051	798	405

Source: Aldoradín 2015.

Agri-businesses also use legal mechanisms to accumulate more groundwater abstraction rights, usually backed by the state. According to the new water Law (Law 29338, of 2010, article 72) (Ministerio de Agricultura 2010b), the state would give priority to those water users with a certificate of water efficiency when it comes to granting new rights (arising as part of the surplus generated by the development of efficient water use)(ibid.). This, according to Cardenas Panduro (2012), would mean that those landowners who can afford to invest in better irrigation techniques will obtain more groundwater permits. The lengthy administrative process to obtain new permits and drill new wells benefits larger farmers with the financial means to employ lawyers to carry out the paperwork and rent equipment to drill new wells (ibid.). Additionally, agri-businesses only rely on a few groundwater abstraction permits to irrigate vast expansions of land. In some cases wells are bought from small farmers outside the limits of the estate and water is conveyed via aqueducts to the irrigation fields. The most striking example of this is a 580 hectare farm with an allocated abstraction volume of 0.5 million cubic meters per year via three official permits, but which actually owns 20 wells and is pumping 9.3 million cubic meters per year (ibid.).

Projections by the ministry of agriculture are extremely worrying (Ministerio de Agricultura 2012). Table 15 already indicates that a large number of wells have been abandoned. Based on extrapolations on groundwater use, and aquifer drawdown, the ministry estimates that in 10 years 76 percent of Ica will be affected by extreme water shortages, with 100 percent of the Villacuri expected to be in this situation. The economic output is estimated to drop by 50 percent. This gives a sense of the urgency faced by the Valley.

4 Groundwater community management in the Ica valley

In 2005 some groundwater users began to mobilize in order to create groundwater user associations. The first one to be created, JUASVI (*Junta de Usuarios de Aguas Subterraneas del Valle del Ica*) was created in 2005 by a group of businessmen (Cardenas Panduro 2012). This decision was mainly driven by the declining levels of the groundwater table, the slow release of groundwater abstraction permits and the lack of representation of groundwater irrigators in the associations of surface water users (Cardenas Panduro 2012; Ore et al. 2012). The JUASVI was created representing 59 users concentrating 10,000 hectares out of a total of 26,000 hectares represented in three other user associations (the two others are surface water associations, assembling 5,000 and 3,000 users respectively and 16,000 hectares altogether) (Cardenas Panduro 2012). The creation of the community of groundwater users in the Ica Valley was sponsored by the regional water administration who recognized the necessity put forward by the users themselves and officially recognized the JUASVI in 2009 (Cardenas Panduro 2012; Ore et al. 2012). In total, 24 percent of all groundwater users in the Ica valley belong to a groundwater association (Scamarone 2008).

Since its creation, the groundwater user association for the Ica Valley has struggled due to the large diversity of users and their characteristics. Small and large irrigators are represented but groundwater rights are private and there are no means to measure groundwater abstraction by the users (Ore et al. 2012). The association has poor regulatory authority over groundwater abstraction and the characteristics of the aquifer are poorly understood due to a lack of hydrogeological and technical studies (ibid.). Moreover, control tasks by the association are difficult as many properties are guarded and landowners do not allow the access to their farms to association representatives. There is also no common regime for groundwater abstraction and users pump continuously day and night (ibid.). According to Cardenas Panduro (2012) the evaluation of the activities of the results of the JUASVI is mixed, as groundwater over-abstraction has continued since its creation (in many instances due to the activities of some of the members themselves). It is possible that the creation of the JUASVI has also used as a factor to reduce the power of the other associations of water users (as the association is controlled by the large agri-businesses) (ibid.).

Small irrigators have nonetheless access to groundwater and since the 1980s, when farm cooperatives were divided and groundwater wells were allocated to private farmers, some farmers formed associations to irrigated with those wells and share the operation and maintenance costs and establish tariffs in case other irrigators would like to purchase water from the collectively owned well (Cardenas Panduro 2012). Given the much higher cost of groundwater, small irrigators would use it only as a complement to surface water. The association of irrigators of the Pachacutec wells owns 6 wells and irrigates 600 hectares of cotton with an annual allocation of groundwater of 2.3 million cubic meters shared between 237 users (Cardenas Panduro 2012).

In view of the serious depletion of the Ica Aquifer, the JUASVI asked for an increase of the surface water transfer from the Choclococha to the Ica Valley. This project was however stopped by the Latin-American Tribunal of Water after a community of users using surface water from the Choclococha appealed the ministerial decree that would have allowed the water transfer project to go through (Ore et al. 2012). The groundwater user association of the Ica Valley views the water transfer as the only viable long-term solution to reduce groundwater dependency for agriculture (Cardenas Panduro 2012).

Surface water has also been used individually by large groundwater users in order to sustain their individualistic and 'predatory' activities (Ore et al. 2012). With the decrease of water supply to the valley, these users have been recharging the aquifer locally using water from the Ica River. Water is taken either from the La Achirana canal which runs parallel to the river and mainly serves small landowners downstream, or from underground pipes transporting water from wells at the head of the valley pipes to private farms downstream (La Republica 2014; Ore et al. 2012). Large water users are also relying on infrastructure projects such as the Tambo dam, a 55 Mm3 dam planned to be built by the PETACC ('Proyecto Especial Tambo Caraccocha', a decentralized body of the Ica Regional government in charge of implementing public investments for infrastructure), to generate electricity and also to store water during the rainy season and for aquifer recharge (Gobierno Regional de Ica 2013; La Republica 2014; Ore et al. 2012).[188] Small dams in the lateral valleys to further store water upstream for irrigation are also

[188] Interview Edson Rios, Director of the Administrative Authority for Water Chaparra-Chincha, 26th November 2012, http://www.observatoriocambioclimatico.org/node/2864 (Accessed 10th May 2015).

being planned by the PETACC and the National Water Authority (Gobierno Regional de Ica 2013).

5 Groundwater over-abstraction and social conflicts in the Ica valley

Groundwater over-abstraction and the expansion of large agri-business farms concentrating and abstracting more groundwater have also brought social tensions and in some cases conflicts to the Ica Valley (James 2015). Most conflicts in the valley are related to the availability of water (Scamarone 2008) and the major conflict is between small and large irrigators, as small landowners have seen their resource dwindle (Ore et al. 2012). In some instances, the construction of new infrastructure to carry water from abstraction points to other irrigation areas within the vast landholdings by some of the large agri-businesses has resulted in social mobilization trying to stop the works and subsequent clashes with the police (Cardenas Panduro 2012). Small farmers are also resisting the expansion of agri-businesses by refusing to sell their land, as they see agriculture as their only livelihood. Some of the offers are below what small farmers want but large farms also offer salaries and work with a stable income (ibid.). The increasing control of the majority of agricultural production in the valley by large producers is difficult to counter for smaller farmers. According to Rendon Schneir (2009), 78 percent of all asparagus production in the Ica Valley came from farms larger than 25 hectares, and out of 50 main companies producing agricultural products in Peru, 26 are located in the Ica Valley.

The development of agriculture by large landowners and agri-businesses was accompanied by funds from the International Finance Corporation (IFC) for one of the large farming industries in the valley, Agrokasa between 1999 and 2006 (CAO 2011). Through three projects, the IFC financed the expansion of Agrokasa's agricultural operations in the Ica valley, acquisition of land and upgrading of farms with drip irrigation. These investments also aimed at restructuring the company's debt obligations, developing the farming industry and supporting 'hydraulic improvements' intended to provide water and reduce stress on the aquifer and included an intra-aquifer water pipeline and, if approved by the government, new wells and/or surface water intakes (CAO 2011).

As a result of these activities, a series of complaints were filled with the IFC's Office of the Compliance Advisor and Ombudsman (CAO) regarding the impact of IFC's funded projects with Agrokasa. The plaintiffs maintained that the company's operations were contributing to the over-exploitation of groundwater in the valley.[189] The final review by the CAO stated that the over-exploitation of the aquifer and the extent of local concerns about the depletion of groundwater by large agricultural landowners were well known to the IFC throughout its due diligence process. Nonetheless the IFC proposed to seek approval by the Board without an appropriate Environmental Impact Assessment ex ante (instead the environmental impact assessment was required as a condition of commitment for the project not as a safeguard of feasibility of the project). This contravened IFC regulation of information disclosure and consultation with potentially affected parties as stakeholders and affected communities did not have access to this information prior to the decision of the board. The issue that the client Agrokasa was committed to year-on-year reductions in water usage was meaningless given the fact that no underlying baseline assessment and understanding of the scale of the depletion of

[189] The CAO was also investigating the project for conflict of interest as the president of Agrokasa was married to a World Bank employee. The conflict in the valley increased in intensity and in April 2010 a World Bank official was shot at by gunmen during a visit to the valley after he had spotted land pockmarked by clandestine wells. Reuters, "Peru water wars threaten agricultural export boom", 9th September 2010, http://www.reuters.com/article/2010/09/09/us-peru-water-feature-idUSTRE6885QF20100909 (Accessed 7th May 2015).

groundwater resources was undertaken (CAO 2011). After months of controversy, the company Agrokasa withdrew the request for funding for the project in September 2010, saying that it did not need the money from the IFC anymore.[190]

A further report by CAO in 2013 referred to the concerns about the over-exploitation of groundwater, which had previously been raised internally within the IFC, however, "commercial pressure to expedite the project, and an absence of effective IFC management support, meant that the professional advice offered by IFC's environmental and social specialists was effectively overruled, and community objections were ignored. The case was closed in June 2013" (CAO 2013: 63). According to Hepworth et al. (2010), this case illustrates a failure of public policy and public institutions, and how insurers, purchasers, and donors failed to take due diligence, the failure of existing lending safeguards and market standards.

[190] Reuters, "Peru water wars threaten agricultural export boom", 9th September 2010, http://www.reuters.com/article/2010/09/09/us-peru-water-feature-idUSTRE6885QF20100909 (Accessed 7th May 2015).

Part 3. Groundwater community management and institutions in Cochabamba, Bolivia

1 Community rules in Bolivia

In Cochabamba, Bolivia, community cooperatives have been formed by small-scale farmers to install deep irrigation wells and electric pumps, manage wells and groundwater allocation amongst the community, allowing them to spread the costs and share the risk of these investments. Additionally, these cooperatives are the receptacle for new institutions. Despite depictions of a 'chaotic' water management system and an ambiguous and overlapping state legal system[191], farmers' groundwater exploitation rules and institutions did not emerge in a cultural vacuum and are sustained by traditional cultural principles adapted from Andean surface water irrigation principles (Stallings 2006). Following Stallings (2006), the majority of irrigation systems in the Andes are a hybrid of customary rules and state law and communities are able to adapt state laws to their advantage, while at the same time maintaining their own rules (Seligmann 1993 and Gelles 1994 in Stallings 2006). Previous ethnographies and historical studies of Andean communities found widespread reliance on informal norms, customs, and systems of private governance conditioning and regulating the use, management, and distribution of surface water for irrigation (Trawick 2001). For Gelles (1994 in Stallings 2006), while these practices and cultural beliefs vary with each irrigation system, there are some basic underlying principles found across the region: water is sacred; water management is ritualized; its distribution is conditioned by local social structures; and local models of irrigation management are affected by history. Additionally, the underlying cultural principles of reciprocity, redistribution, equilibrium, equity and duality sustain community property arrangements in these communities (Stallings 2006).

Research in the upper Cochabamba valley by Stallings (2006) analyzed the emergence of property rights and the institutional arrangements organizing the use and management of groundwater. Her research found that infrastructure maintenance, allotment and distribution of water, conflict resolution, monitoring and enforcement of rules all happened at the local level. Moreover, groundwater communal irrigation systems maintain community unity and social interaction via the participation of all the members in decision meetings, alternating the roles within the cooperative, organization of rituals and parties.

2 The groundwater cooperatives of Mallco Rancho, Cochabamba[192]

The study of groundwater cooperatives in Mallco Rancho sheds more light on the different processes used by farmers to manage and allocate groundwater. The community of Mallco Rancho is located 23 kilometers from Cochabamba city and has a total cultivated surface area of 387 hectares. Both surface and groundwater are used for irrigation. With insufficient access to surface water for irrigation, wells have been drilled since the late 1970s. This was part of a state-led research program on groundwater resources which installed monitoring wells during that decade (which were then later transferred to the community and transformed into production wells) (Duran 2015b). Initially, irrigation water users were not interested in them due to local superstitions (it was believed that groundwater belongs to the devil) but younger generations at the time with less access to water and land saw them as an opportunity to increase agriculture

[191] Following Stallings (2006), the 1967 Constitution states that water is state property but meanwhile the 1906 water law asserts that water belongs to the individuals that own the land through, or under, which the water flows. Although the constitutions is above all other laws the 1906 law remains in effect as no other law takes into account what the constitution says about water.

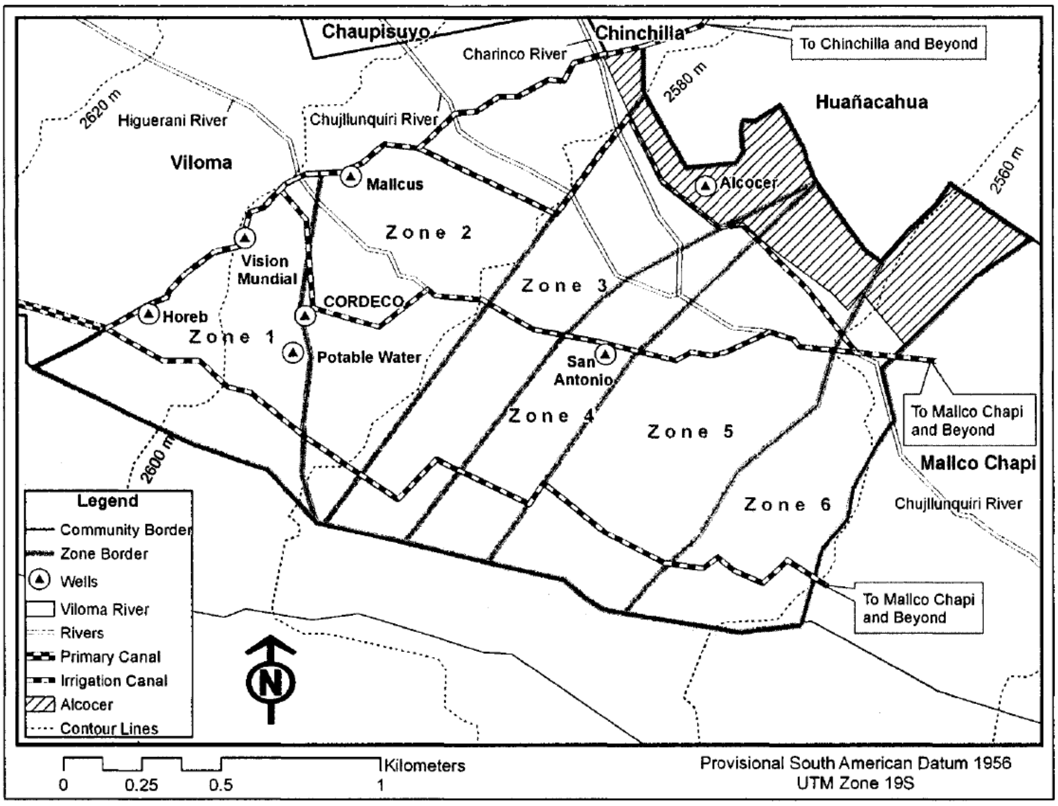
[192] The information used for section 2 to 5 comes from the study by Stallings (2006) with complements from Duran (2015, personal communication) where indicated.

and improve their livelihoods (ibid.). This younger generation benefited also from this situation as the state covered all the costs of the wells (drilling, abstraction, and maintenance). This situation led quickly to the improvement of living conditions and the expansion of agriculture in the area of the Valle Central (Mallco Rancho).

Most of the wells that appeared are communally owned irrigation wells through cooperatives but each one of these communities present differences. Their depths (70 to 120 meters,) flow rates, area irrigated, number of users and membership fees vary (these are one-time fees to cover the cost of drilling the well, installing electricity, purchase of the pump) as well as management rules, giving way to a diverse group of cooperatives, each of them with different mechanisms to manage and allocate groundwater amongst its members.

There are five communal wells in Mallco Rancho and one well supplying potable water to Mallco Rancho (Figure 86). Irrigators have also the right to use surface water from the Viloma River which is further south. Water access to this river is controlled by the Viloma River Users' Association. Water turns are established since the 1930s and allocated according to the influence of each community along the river when the rotation was determined. During the dry season, surface water is complemented with groundwater. Of all community households, 85 percent belong to at least one groundwater irrigation system and only 8 percent solely rely on groundwater. Each groundwater cooperative in Mallco Rancho is organized around one of these 5 communal wells. The different locations for the wells in Mallco Rancho were a result of the donation of sale of land plots and groundwater is distributed along the same canal network as surface water.

Figure 86. Community zones, communal wells and irrigation canals in Mallco Rancho



Source: Stallings 2006.

The first well in Mallco Rancho was drilled in 1974 by a government-funded development agency. Although the well was used initially to study the aquifer, the urging need of potable water for the community converted it into the community's potable water well as its limited flow could not be used for irrigation. Membership in order to gain access to the water was 150 USD as an initial fee, plus a monthly fee for unlimited access. Original community members were offered a reduction in their membership fee in return for a contribution in labor for the installation of the pipe network system.

The success of this first well coupled with the success of other study wells in the region gave the farmers the stimulus to use groundwater to irrigate their crops. Additionally, the fact that Mallco Rancho had access rights to less hours of surface water from the Viloma River due to an inherited system of land distribution between different types of communities, also played a role in the farmers' desire to drill wells for irrigation. This first cooperative supplying domestic water had its well in April 1978 and with 76 member is the largest cooperative in the community (as many farmers joined at the beginning since it was the first one) and one of the least expensive to join (with membership fees of USD 500). The different cooperatives in Mallco Rancho are run by their users without state interference and set up autonomously. Although state laws exist, these cooperatives function according to traditional community rules. According to Stallings (2006: 88), Mallco Rancho residents are aware that there are state rules regulating groundwater (e.g. groundwater is owned by the state) and they also know that "if enforced [the laws], could be to their disadvantage. As such, the farmers fear that at any given moment the government will start charging them for their surface water and/or groundwater use."

A severe drought in 1980 led to the drilling of a second well and the creation of a second cooperative. The farmers represented in this new cooperative felt that their land plots were too far from the first well in order to join the first cooperative. Additionally, farmers also suspected that there would be important losses through evaporation from the open dirt canals used to carry the water abstracted from the first well. Moreover, this second group of farmers thought they would do a better job at managing their own well as they mistrusted the first cooperative, as the farmers were all from the upper irrigation zone. With 36 members, this second cooperative purchased three electric pumps with financial help from Canada and USAID. The third cooperative in Mallco Rancho was created with 45 members and it arose also due to a lack of trust between these 45 groundwater users and the management and members of the first cooperative after another severe drought in 1985. One of the members donated a plot of land for the well, which eventually was purchased by the cooperative.

3 Membership costs, loans, and joining a cooperative

For community members, the most constraining factor to join a community-led cooperative managing a well (as a joint investment with endogenous rules) is the membership cost. Small-scale farmers do not have access to credit markets as banks usually demand the borrower's landholdings as a loan guarantee, which poses a problem as many farmers do not hold an official title to their land. Additionally, due to diminishing land values, most farmers do not own enough land to cover the amount of money they need to borrow. Repayment terms are also generally too short for small-scale farmers to pay back the debt owed to the banks. As a result, many informal arrangements have appeared, such as informal loans lent by one of the groundwater cooperatives with access to a bank account or by informal lenders based on verbal agreements (from friends or family to an individual). Repayment periods for the loans are usually between two months to a year.[193]

The reputation of the groundwater cooperatives in the Mallco Rancho community is based on their management and also enforcement of sanctions. The San Antonio Cooperative is considered to be the best managed. Others have less reliable groundwater flow or its members are amongst the wealthiest farmers in the community. Others are run on a day-to-day basis more chaotically and meetings held infrequently, fines are not enforced or paid and directors do not uphold sanctions (for two groundwater cooperatives).

4 Rules of procedure of the groundwater cooperatives

Each groundwater cooperative is managed by an independent board of directors and consists of a president, secretary, treasurer and two 'vocales' (two cooperative members supporting the board). Two of the cooperatives have also a vice-president. Although members of the board are meant to rotate annually, the same individuals tend to hold the same positions for several years. This is due to the belief that some members of the cooperative are more knowledgeable than others in irrigation and finances. Another important member of the cooperative is the pump operator who is charged with distributing groundwater to each member. Two of the cooperatives in Mallco Rancho rotate this position amongst their members on a weekly basis (excluding the directors) whilst all other cooperatives have a permanent paid pump operator. The rotation of this position keeps all members of the cooperative accountable. This position oversees the switching on and off of the pump, has the keys to the well, and notes the kilowatt-hours used by each irrigator, collecting also the irrigation fees.

As a divergence from the surface water irrigation system, rights to groundwater are attached to the shareholder and not to the land and these can be sold separately. Additionally, individual rights within each cooperative are equal regardless of the member's landholdings and all members contributed equally to the drilling costs, installation of electricity and construction of the well house. Members pay for their hourly irrigation water consumption, cost of electricity, supplies for bookkeeping, maintenance of the pump and every shareholder in the cooperative is assigned the same number of irrigation hours every certain number of days.

As part of the Andean tradition of natural resource management, the rights of a community to irrigation are attached to a certain number of obligations. In the groundwater cooperatives of Mallco Rancho, members have to contribute labor, accept rotating leadership positions and participate in meetings in return for the use of groundwater. Participation in the normal functioning of the cooperative and community evens builds a sense of unity and pride within the community which maintains a high rate of rule compliance and strong sense of obligation towards the cooperative. The allocation of groundwater within the cooperative is done either on a first-come first-served basis or on the basis of fixed groups of members with rotating irrigation turns. Some cooperatives operate with one set of allocation rules all year round and others change to a first-come first-served basis during periods of low demand.

[193] Transaction costs for both formal and informal loans tend to be high although informal loans tend to have less risk associated as lenders and borrowers know each about each other (including how much land they own, how much they produce and what other kinds of debts they have). This knowledge reduces the lender's risk as they also take into account additional information that would be acceptable by formal lending institutions (trustworthiness, work habits, and honesty of the borrower). Farmers can also obtain money without having to ask for a loan such as selling or renting out a land plot, selling or renting out a house or a room in the house or selling dairy product. Some older members own more than one house and they rent it to newer members of the community.

Exchanges between neighboring irrigators are also possible so that instead of each one having three hours of water allocated for a day, they can both have 1.5 hours of water on two different days. This allows farmers to have more flexibility and permits them to irrigate their fields more frequently. Debt payment can also be settled between members of a cooperative by transferring volumes of groundwater. In addition, members who sometimes cannot pay for the entire share often trade it or sell it to members with greater water needs or those with more land.

5 The groundwater cooperative of San Antonio, Cochabamba

The case of the groundwater cooperative of San Antonio in Mallco Rancho, Cochabamba, is used to present the diversity of rules, flexibility, and refinement of institutional arrangements amongst groundwater irrigators. One of the most important obligations for the members of the San Antonio groundwater cooperative is the attendance at cooperative meetings. The cooperative strictly enforces this rule as the attendance is seen as imperative to sustain the group's integrity and a fine is issued for every meeting a member misses. In addition to the fine, members are labeled as disrespectful to the group if the non-attendance persists. Members also have to pay for their hourly groundwater use so that the cooperative can pay the monthly electric bill for the operation of the pump. A difficulty arises here though, as members are accustomed to free surface irrigation water and have experienced a hard transition to pay for their groundwater. Another issue related with fee payment is that many farmers do not have a stable financial income which causes them to delay their payments. Rules for the payment of fees were adjusted to better enforce payment (initially the cooperative gave 2 weeks but over time the period was reduced to 7 days as members became more used to paying for water). Members are also assigned to committees to perform different sorts of tasks.

Members are also expected to take week-long turns as pump operators. The pump operator is required to record data from each member's irrigation turn, including KWh used, total hours of water consumed, amount due, and amount paid. The pump operator must also collect any balance due from each cooperative member, give the member a receipt and submit the money to the treasurer who logs the payment into the official accounts book.

Groundwater allocation is based on the rule of irrigation groups and the members of each group decide the order of irrigation turns. Some groups regularly rotate the order of irrigation and other groups keep the same order. The boundaries of the cooperative were delimited geographically and only community members with land east of the main street where allowed to join. This rule was established in order to reduce loss of water through evaporation and transpiration as it travelled through open dirt canals.

The use of sanctions is decided during the cooperative's monthly meetings and also during daily conversations between groundwater users. Sanctions can arise when members do not pay their fees, or fines for not showing up at meetings, or when the pump operator has failed to fulfill the obligations of the position (failing to record the electricity consumption of each irrigator, failing to give receipts, not collecting all the money due or not handing it over). Verbal admonishments are used as a first measure to encourage violators to pay their debts but if these do not suffice monetary sanctions are administered for failing to fulfill obligations associated with meetings, payment for irrigation or participation in repairing projects and assigned committees. More severe sanctions can also be used such as the restriction of temporary rights or as an extreme measure expulsion. If despite the sanctions problems persist, the cooperative has the possibility to create new or more severe sanctions to curb the problem. All members participating at the monthly meetings vote by raising hands on the modification of sanctions and the proposal with the most votes will go into effect.

Although some conflicts can arise, usually involving members not paying their fees and fines or because the pump operator has failed to fulfill the obligations of the post, these are rare. In a matter of 5 years (1996 to 2001), Stallings (2006) reported only 3 instances of conflict involving the non-payment of fees or the non-payment of money by the pump operator to the treasurer. In this last conflict, the cooperative had never experienced this type of behavior and had to approve a new sanction to deal with this situation. In the two other instances external mediation was sought. In one case a lawyer was hired to revise the statues of the cooperative and dictate the amount due. In the other conflict the mayor of Mallco Rancho intervened.

Irrigation associations can become arenas for matters other than irrigation and in Mallco Rancho the flows of money used to invest in wells and to join groundwater cooperatives have allowed the establishment of a system of loan schemes granted by the cooperatives. These loans are, in the groundwater cooperative of San Antonio, registered in the *Libro de Actas* (Cooperative official registry) and a separate document normally outlines the condition of the loan, the interest rate, and collateral. This new function as loan guarantor and issuer arose partly due to the difficulty to obtain loans from commercial financial institutions and the fact that the cooperative has a bank account. The use of the funds from the cooperative's account to grant loans earns the cooperative a higher interest rate. Despite this system the cooperative has experienced some problems with granting loans, such as the co-optation of funds by the president and treasurer for personal reasons. This situation sparked however a healthy debate within the cooperative and new rules for loans were defined such as a cap on the amount available for individual loans (a maximum of USD 200 for a six month term and a 2 percent interest rate). Members needing a loan had to organize into groups of five for a total of USD 1,000 granted per group.

6 Discussion about groundwater cooperatives in Cochabamba

In the community of Mallco Rancho, groundwater cooperatives have been created to improve access to water for irrigation. These cooperatives have evolved and become an integral part of the communal live of farmers. These institutions have also adjusted and standardized their rules, adopting some of them from previously existing surface water rules but also creating new ones specific to the management and allocation of groundwater.[194]

Rules however differ between cooperatives. One cooperative in Mallco Rancho does not grant loans but its members have received several benefits such as a community centre for meetings, gatherings and parties. The cooperative also installed public bathrooms with shower facilities in the building. The development of these cooperatives has not been chaotic but controlled and

[194] The members of these groundwater cooperatives have drawn on their experience in surface water irrigation and have applied, adapted, and shifted the principles having informed their traditional irrigation practices. Thus, traditional concepts of natural resource management such as equity and reciprocity have also surfaced in groundwater management practices. Cooperatives use learning, adaptation, and flexibility to become increasingly efficient and better managed and providing additional services other than supplying groundwater. However, in contrast to traditional surface water irrigation, which has a very low monetary cost, groundwater irrigation practices revolved around financial flows. Money is required to become a member of the cooperative, maintain infrastructure, and access water. Thus, groundwater cooperatives have mainly become arenas for economic activities and emerged as important providers of financial services to their members. Despite that, groundwater cooperatives also help maintain the cohesion of the community. Conflict resolution in these cooperatives tends to have low transaction costs and members usually work together to resolve the issue. This process sometimes improves the governance of the cooperative as new rules are approved to deal with the issues causing the conflict.

structured. Via various rules, such as the rotation of the role of the pump operator or the involvement of its members in deciding and voting new rules, cooperatives maintain equity and equilibrium in these communities.

These cooperatives however have, at times, required external support, especially due to the fact that groundwater abstraction technology is fairly new in the community and it requires technical expertise to drill a well or to repair it. Some of these cooperatives have also received help from the government and international aid organizations for investments in infrastructure (wells, housing, and sanitation or drinking water supply network). Groundwater cooperatives have also learned to seek help when needed, such as consulting with engineers for appropriate fees for hourly groundwater use, or hiring lawyers to resolve contractual problems. This support has also enabled the cooperatives to improve their functions and to consolidate their structure and place within the community.

The issue about the success of these groundwater cooperatives remains localized as these communities are fairly homogenous in their socio-demographic structure. They are small and the use of water is limited to small land plots. That does not mean that these communities are not active, as proven by the events that took place in Cochabamba in 1995. New wells drilled by the drinking water utility from Cochabamba around the area of Mallco Rancho and other local communities were viewed by farmers as detrimental to their use of groundwater for irrigation. Farmers marched across the valley and to Cochabamba to protest against the drilling of deep wells. In the end these protests were successful as the plans were abandoned and the governor resigned. The autonomy of these cooperatives seems to be paramount, with full accountability of the board of directors to the group of members. Despite the organization of users in these communities being heavily regulated internally, Duran et al. (1997) and Duran (2015b) emphasize the lack of central planning by the state and the poor situation vis-à-vis the management and regulation of groundwater resources in Cochabamba.

7 Groundwater use for urban areas in Cochabamba[195]

In more urban areas of Cochabamba, similar systems of community management are also in place in order to manage water resources for urban settlements. The events that followed the attempted privatization of water resources and management and the fight by rural and communities, have been seen by some researchers as the struggle against the disruption of common pool resource management and the institutions linked to it (Perreault 2006 and Baker 2007 in Wutich 2009). The research by Wutich (2009) also showed that historical principles of Andean irrigation management systems have found a way to work in an urban setting and that therefore these are embedded in a cultural knowledge of water management. Further research by Marston (2014: 72) found that these urban water committees have transformed "their water systems from informal to quasi-formal". They have adapted their rules and procedures, organizing themselves under a wider organizational umbrella, and affiliating themselves with state-sanctioned units of decentralized governance so that they can be more temporally stable (Marston 2014).

The industrial development of the area as well as the urban expansion of Cochabamba has brought a series of challenges to the management of water resources in the area. Pollution and over-abstraction are threatening the aquifer system from which the city of Cochabamba obtains its water supply and urban development has brought serious inequalities in terms of water

[195] The information used for this section mainly comes from the study by Wutich (2006 and 2009) with complements from Duran (2015, personal communication) where indicated.

access between richer and poorer neighborhoods within the city. Newly developed squatter settlements in the south of the city have no or poor access to water due to a lack of historical entitlement to municipal services (Wutich 2009).

The settlement of Villa Israel in Cochabamba obtains its water resources from two small wells located a 30-minute walk from the community. Water is owned by the community and the settlers have adapted rural water-management principles to create a new set of rules for the urban context. Water is managed by the settlement's local government via an organization called the Neighborhood Council. Only community members are eligible to receive water from the wells and to be considered as community members, households need to own land within the formal boundaries of the community and send at least one member to participate in the various community governance structures. Once a month, the Neighborhood Council holds an open-air meeting in which the management of the water system can be discussed and modified. Water is allocated via tapstands and the responsibility for funding, constructing, and maintaining those tapstands falls on user groups, a nested enterprise within the Neighborhood Council.

User groups consist of informal interactions amongst neighbors in a roughly delineated area. To get access to water, community neighbors need to pay a fee every two months that gives them access to the local tapstand via a yellow punch card that is used to show that each household has paid their fees for the shared tap. The 'uniformity rule' is implemented as every household has access to 40 litres of water per day. Water distribution is supervised by a community elder paid by the community. He unlocks the tapstands and follows a strict rotation system through which water is distributed in 20-minute blocks. The tapstand supervisor blows a whistle to let neighbors know that he has opened the tap. Due to water scarcity, sometimes the full rotation is not possible as the water distribution system sometimes runs dry before each tapstand has been opened. When that happens, the supervisor starts the following day from the point at which water ran out. The tapstand supervisor has another important role which is to monitor the level of groundwater in the wells and to adjust the allotted output for all tapstand users if the water is low. This ensures that the system is not over-exploited and that there is a proper balance between use and availability of the resource (Wutich 2009).

The main principle governing water allocation in Villa Israel is regularity. This principle ensures that water cutbacks, especially during times of scarcity, are apportioned to all community members equally. Despite dry season and stress over water resources, the adoption of flexible rules in the community sustained the allocation of water and did not undermine fairness, equity or overall subsistence ethic. These institutions had therefore the ability to remain ecologically and socially sustainable during periods of stress (i.e. dry periods). However, these social structures were prone to disturbances in the form of corruption (e.g. with one of the presidents of the council) and also the interference from non-members of the community (i.e. renters of houses and non-proprietors representing the most vulnerable groups within the community). When the government of the council would not function properly, they would use internal conflicts and power struggles between community members to make their voice heard in the Neighborhood Council and try and obtain gains for themselves (as they are excluded from the community governing system and cannot vote or officially receive water through the tapstand system) (Wutich 2009).

In Villa Israel, monitoring of rules, sanctions and conflict resolution occur in four different levels. The Neighborhood Council is responsible for distributing tapstand cards and when necessary resolving conflicts during general meetings. The second level concerns the interpersonal relations between users. All community members are responsible for making sure that rules are followed. This takes the form of gossip, and visits to neighbors by other community members.

Another level of rule monitoring is at the tapstand, where community members gather when someone is caught breaking the rules. The last level of monitoring and conflict resolution is the tapstand supervisor who has the final word on what will be allowed or not, although if there is a wide group consensus as to the behavior of the user is according to the rules or not, he will follow it. Rule violations can range from outright theft (rare) to renters (non-community members) receiving water, to legitimate tapstand users being inconsiderate of others (Wutich 2009).

Users can also exchange and loan water to each other and the 'repayment' of the loan is expected to happen as soon as the neighbor’s water supply for the day has been replenished. However these exchanges happen out of necessity as general reciprocity of water exchanges was not observed by Wutich (2006) (86 percent of households stated that they did not borrow water) although some poor families were observed to be engaging in such water exchanges. The repayment of water can also be done via lending services or part of a larger reciprocal exchange involving two households (looking after the house, repayment with food) although these tend to happen almost exclusively between relatives and those living close by to each other (Wutich 2006).

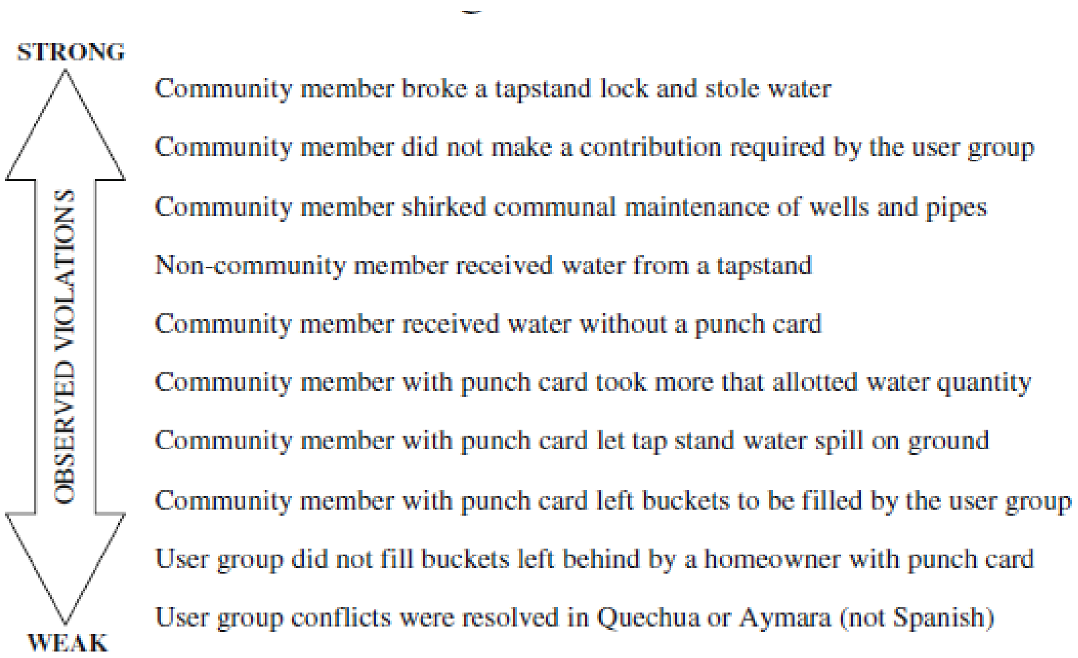
The intense urban development of this part of Bolivia has represented an additional pressure on groundwater resources (Duran 2015b). The initial irrigation boom brought more inhabitants to this area and a conflict for the allocation of groundwater for urban and agriculture uses appeared (ibid.). Without any state control of wells or abstractions,[196] urbanization increased driving even more so the demand for groundwater causing a decrease of the groundwater table and service delivery levels in most of the 600 well cooperatives in the Valle Central (ibid.).

According to research by Duran (2015a), in a case study in the Upper Valle Central in Cochabamba, 200 new wells were drilled between 1998 and 2012 (for all types of uses, industrial, domestic, and irrigation). Despite such increase, volumes abstracted remained relatively stable, indicating the limitation of the availability and exhaustion of the resource (only 31 percent of groundwater volume abstracted versus a 300 percent increase in the number of wells during the same period) (ibid.). The over-abstraction of groundwater in this study area led to a 15-meter decrease of the static groundwater level between 1998 and 2011 (1.15 meters per year on average) (ibid.).

The lack of new infrastructure projects (the USD 214 million Misicuni Multi-Purpose Dam Project aiming to supply water to Cochabamba is not being completed) creates a very high dependency of water supply on groundwater. Diminishing groundwater resources in these areas have also led to strategies of appropriation by newcomers in new Neighborhoods without consultation or coordination with already existing residents (when a new set of houses is built, a new well is always drilled without asking neighbors) (Duran 2015b). Access to existing wells can be subject to high financial costs as new members are rarely accepted. Rent-seeking from drilling companies and local leaders has also been observed as they will try to convince residents of the need of a new well which, when drilled, will not be productive enough (due to design or construction flaws) (ibid.).

[196] Bolivia’s water law dates from 1906 and the 30-odd attempts to update it with a new law have failed (Duran 2015).

Figure 87 Institutional rules established in Villa Israel and broken during research arranged from strongest to weakest violation



Source: Wutich 2009.

Part 4. Groundwater governance in Chile and the Copiapó Basin

1 Groundwater regulation, legislation and abstraction rights in Chile

1.1 The 1981 Water Law

Chile has had four water legislations in the twentieth century: 1950, 1969, 1981, and 2005 (this last one was the reform of the 1981 legislation). The 1981 Water Law regulated the access and use of groundwater, granting perpetual property rights (which could also be transferred and sold) to applicants. This legislation also separated the use of groundwater from the authorization to drill a well: the application for the right was not subject to its use nor to the ownership of the land above it. This represented, according to Godoy (2010), the legalization of a right of capture of the resource as long as it did not affect any right from other users. The 1981 Water Law also established two types of groundwater use rights: 1) temporary rights; and 2) permanent rights. These were issued by the General Water Directorate (DGA), the acting regulator and water resource management agency in Chile.). Temporary rights are intended for "situation when there are uncertainties about the aquifer's resources – provisional water rights can be revoked if impairments of previously granted rights are verified" (Bitran et al. 2014: 847).

Permanent rights are indefinite rights "whose overall allocation should be consistent with the long-term recharge capability of the aquifer" (Bitran et al. 2014: 847). Once granted, these rights are considered private and protected by the Constitution. This was done in order to create water markets for water rights which could efficiently set up a price reflecting the opportunity cost of the resource (Bitran et al. 2011). The market was set up as the most effective and efficient way to allocate and exchange water rights (Dourojeanni and Jouravlev 1999). However, barely any structure or rules (registry of users, appropriate definition of rights, conflict resolution mechanisms, hydrologic knowledge) were established or ensured by the 1981 Law in order to properly organize such exchanges (in addition of the lack of infrastructure to transfer water sold) (Donoso 2003; Dourojeanni and Jouravlev 1999).

Additionally, payments for transferred water rights usually end up being higher than the initial price established by the market due to speculation, real water availability, or right owners reticent to give up and sell their rights (67 percent higher on average) (Valenzuela et al. 2013). Users also prefer to hold on to their right and not sell despite having to pay a fine for not utilizing their right since 2005, as the price they can obtain from selling can be up to 22 times the value of the fine (Arellano 2013b).[197]

Research by Prieto (2016) in the Atacama Desert attempts to debunk the assumptions that Chile has one of the most unregulated water management systems in the world, maintaining that the state remains the central actor in Chile's water allocation system. Market transactions have been infrequent with little reallocation of resources, serving more the purpose to securitize private rights than to incentivize market exchanges (Bauer 1998 and Hearne and Donoso 2014, in Prieto 2016). Moreover, Prieto found the dispossession of surface water rights from local communities towards mining companies. Water transactions in volume were found to be very small compared to the total stock of water rights granted directly to them [mining companies and urban water supply companies], under either the previous water regimes or the original allocation process established by the Water Code of 1981.

According to the 1981 Water Law in Chile, any user can submit a request for a right to abstract groundwater, without much restrictions or conditions. Any user with the right to use

[197] In 2005 the government introduced after 13 years of discussion a modification in the 1981 Water Law. Amongst the changes, the modification stipulated that users having obtained a right and not using during a certain period of time would have to pay a fine (initially it was going to be 5 years). The aim was to re-assign water rights to more productive activities and reduce the speculative moves of some water right owners (Valenzuela 2009).

groundwater has also the right to abstract it (Article 8) and can build or undertake whatever procedure in order to exercise such right (Article 9). Rights are acquired through mere registration (Article 20). Only some basic technical characteristics are required, including the amount of groundwater *aimed to be* abstracted (expressed in volume and time) and the location of the abstraction point (i.e. well) (Article 140). The 1981 Water Law stipulated that water use rights granted prior to the Law and not quantified in terms of volume or time will be established by equating them to the maximum flow abstracted during the 5 years before the enactment of the law.

As long as there are no objections from other users to the requested right, and as long as the request is duly submitted and the resource is sufficient, the right will be granted (Article 141). According to the law, if there is competition for the same resource (more rights being requested than resource available), the DGA will auction the grants and users paying the highest price will be granted those rights (Donoso 2003).

The right to abstract groundwater entails the power to benefit from all necessary easements for its exercise. The right to abstract, once granted, becomes 'private property' of the user granted for perpetuity and can be registered as such in the Registry of Water Property (article 114) (Donoso 2003).[198] This procedure allows users to ’secure' the right (which should be considered as a 'concession', as water is technically owned by the state)[199] and turn it into private property essentially. The right is not linked to the effective use or abstraction of groundwater (the use does not have to be justified) as the right once granted can be used or not (and users can use it whenever they want) (Dourojeanni and Jouravlev 1999). This would effectively subordinate the public right to the privative use of that same right.

Before its reform in 2005, the 1981 Water Law stated that the DGA could only deny new water use rights if an aquifer had been declared 'zone of prohibition' or only issue temporary rights if an area was declared 'zone of restriction (Bitran et al. 2014). This however could only be done if users had requested such declarations in the first place to the DGA. The DGA had also the obligation to grant all water use rights submitted prior to the declaration of prohibition (provided that they fulfilled the required conditions for submission). With the declaration of a 'restriction area', the DGA can request the installation of water meters and users can be asked to submit the readings regularly to the DGA (Donoso 2003).

The DGA can provisionally grant use rights (provisional rights are temporary) in areas with declared restrictions (Article 66). In such areas, the DGA can also 'prudentially' limit new wells. These provisional rights can be transformed in permanent rights five years after being granted, as long as users demonstrate that they have not suffered any damages or reductions in the volume abstracted as part of the provisional right initially granted. Thus, the DGA had limited faculties and powers and was obliged to grant rights provided that they fulfilled the requirements (Dourojeanni and Jouravlev 1999). Therefore, according to these authors, water rights in Chile were pretty much issued 'unconditionally' (ibid.). The DGA had weak regulatory powers and could not cope with the majority of water conflicts, which had to be resolved by the user communities or by the courts without much understanding of experience in water law (ibid.).

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[198] The Constitutional Court however sentenced in 1997 that as long as the right has not been granted, the resource is property of the state (Donoso 2003).

[199] According to Article 5 of the 1981 Water Law, water is a ‘national good of public use’ and its use is ‘granted to individuals as a right of use’. However, article 24 of Chile’s constitution at the time recognized that the rights of users over water granted these same users the property over the resource (Dourojeanni and Jouravlev 1999).

1.2 Further regulation and legislative reforms

Even though the Water Law was reformed in 2005 (after 15 years of political debate and stalemate), most original articles as well as the spirit of the law were maintained (Bauer 2015). The 2005 reform of the Water Law sought to regularize the situation of irregularity of groundwater rights. The DGA was therefore allowed to deliver permanent abstraction rights to any abstraction of less than 2 litres/second as long as they had been established prior to the 30th of June 2004 and justified with a mere declaration from the user. The deadline was established for the 16th of December 2005 and 500 applications were submitted for the whole Atacama region, of which 300 were located inside the Copiapó Basin, representing an increase in abstractions at the basin level of 600 litres per second).

The reform of the 1981 Water Law in 2005 included provisions to improve water rights title information and records, as well as strengthening the management of abstractions for groundwater and strengthening the control and regulation over new abstraction authorizations (but not of previous ones) (Bauer 2015; Valenzuela 2009). The reform introduced environmental flows, with the possibility by the state to reject new rights in order to preserve the environment. The reform also introduced the need for a justification for the use in the application procedure for water rights, as well as a fee in the case of non-use of water rights and the need to inform the government of any water rights transactions (Bitran et al. 2011).[200]

A modification in 2012 of groundwater regulation in Chile by the Ministry of Environment introduced reforms for wells and groundwater abstractions in areas designated as 'public goods' (national parks, other areas protected by the state, officially designated wetlands, or areas previously designated by the DGA as protection areas) (Ministerio de Medio Ambiente 2012). Even if this modification did not introduce major changes to privately owned rights, the reform specified new rules for well application permits and restrictions in case of aquifer depletion. This Regulation (ibid.) stipulates that any new request for groundwater abstraction permit in these areas will have to include the location of the land plots where the well will be drilled (Article 5), and a technical report on the well, and in case there are noted environmental impacts arising from the well its owner will have to submit a report stating the types of measures that will be carried out in order to prevent aquifer deterioration (ibid.).

Under normal situations, the DGA will authorize any groundwater abstraction as long as the request indicates the location of the well, that there is proven existence of groundwater and that the needed flow has been confirmed and is in agreement with the existing groundwater resources in the area (e.g. water balance with recharge and abstraction, already committed water rights) (Article 19 and 20). The request will have not to interfere with existing surface water flows (thus acknowledging, as did the 2005 Water Law, the interdependence between surface water and groundwater). There should also be a safe distance of at least 200 meters between the new well and other existing wells in the area (ibid.).

Through this reformed regulation the DGA can also restrict groundwater pumping in an area if there is a risk of depletion of aquifer levels that could affect the already established and authorized groundwater rights (Article 31). Groundwater abstraction could also be restricted if granted or committed groundwater levels are higher than recharge or if technical studies show that groundwater demand could cause a reduction of over 5 percent of aquifer storage levels in 50 years (Article 30) (ibid.). Restrictions can also be imposed when abstraction in one hydrogeological sector affects another or if there is a risk of pollution.

200 The 2005 Water Law reform also introduced a new requisite in the procedure to request water rights: the submission of a proposal justifying the use of groundwater and establishing the volume to be abstracted and associating it to its future use (Valenzuela 2009).

In 2013, a proposition to further reform the water law was put forward by the Commission of Water Resources and Desertification of the Chilean parliament. This was, as Chile's president put it in 2014 "a deep and structural change for water management" with future water rights issued for a maximum of 30 years and a fee or 'royalty' for the use of water by users. Water rights granted prior to this new modification will not be affected and will therefore remain granted in perpetuity (Pizarro and Marticorena 2014). The new project of reform aims at limiting water rights in case these are not used, establishing a maximum period of 4 years of non-use for new granted wells after which these rights will return to the state and between 12 and 14 years for historical rights (ibid.). As of April 2015, this reform project was still being debated and studied by the Commission of Water Resources at the Chilean Parliament.[201]

2 Groundwater in the Copiapó River Basin

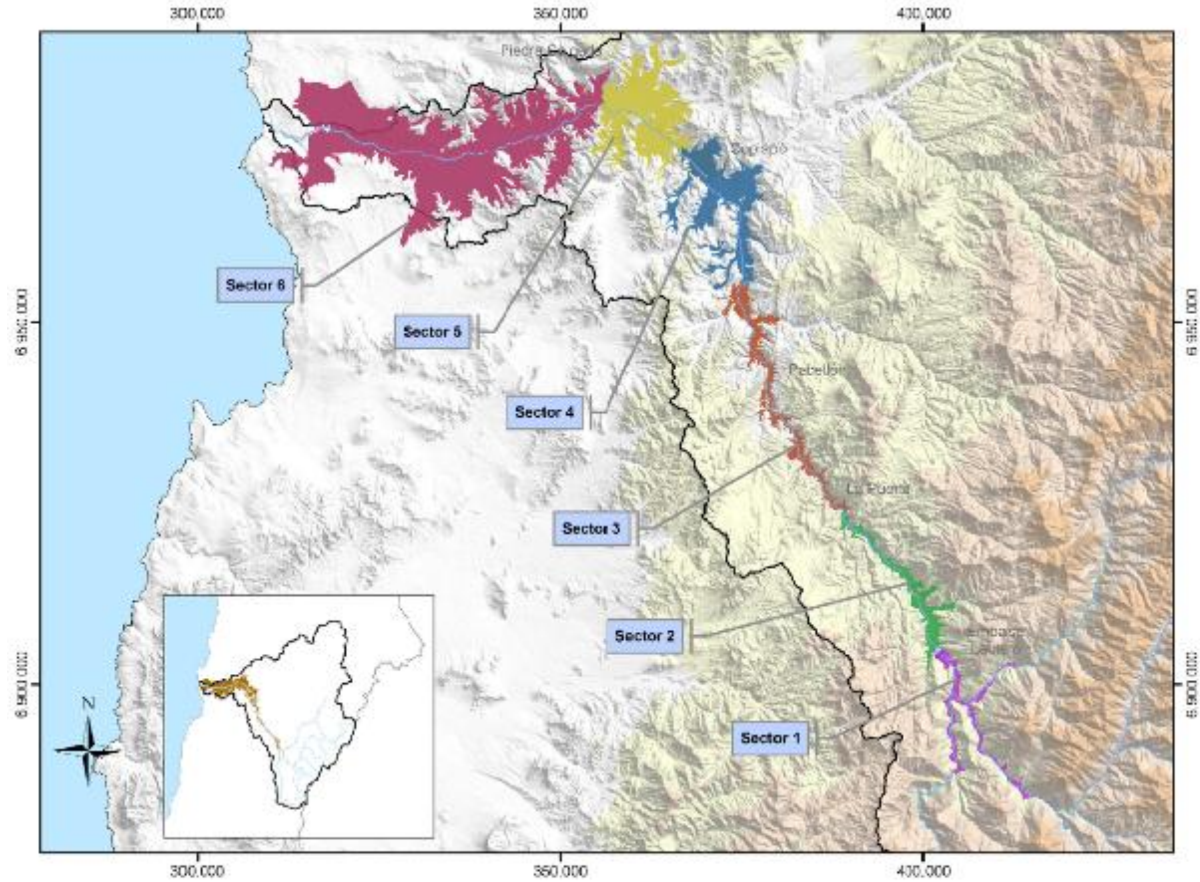
The Copiapó River Basin covers an area of 18,538 km2 in the Atacama Region, in the North of Chile, with the river stretching along more than 180 kilometers, running north-east from the Andes Mountains to the Pacific Ocean. The main geological formations found in the Copiapó Basin are non-consolidated sedimentary deposits (gravels and sands) made of permeable to semi-permeable layers (with an average saturated thickness of 150 meters) with intergranular porosity generating artesian to semi-confined aquifer formations (DGA 2010; Golder Associates 2006; Montero Moraleda 2012). The aquifer has been divided into 6 main sub-aquifer units (or Sectors) and the first three sub-units found in the upper River Basin have very low permeability (Figure 88) (DGA 2010). Before the basin became 'closed' in the 1990s due to important surface and groundwater abstraction for agriculture and mining activities, there were 7,600 hectares of wetlands. Irrigation in the Basin is done either with surface water through canals (3 main canals and 66 secondary canals) diverting water from the Lautaro Dam (42 Mm3) or from groundwater wells (DGA 2009a).

2.1 Groundwater over-abstraction in the Copiapó River Basin

The first census of wells in the Copiapó River Basin was carried out in 1963 and found 18 wells (abstracting around 5 Mm3 per year). In 1987 the DGA had registered 167 wells and in 1995 estimates based on a field survey by the DGA counted 440 wells, 231 of which were working and 207 were out of use (Montero Moraleda 2012). Of those 231 wells, 138 had rights, 45 had applied for the right and 46 had no right to abstract groundwater (Golder Associates 2006; Montero Moraleda 2012). In 2003, Golder Associates (2006) counted 442 wells with 298 operating. Estimates in 2006 considered the total volume of groundwater rights granted and pending for approval by the DGA to users at 667 Mm3 per year for 407 wells (Montero Moraleda 2012).

[201] Sesiones Comision Recursos Hidricos y Desertification, Camara de Diputados de Chile, http://reformacodigodeaguas.carey.cl/wp-content/uploads/2014/09/Documento-con-seguimiento-de-la-Historia-legislativa-del-proyecto-de-modificacion-al-Codigo-de-Aguas.pdf (Accessed 29th April 2015).

Figure 88. Aquifer administrative sectors in the Copiapó Valley



Source: DGA 2010.

One of the causes of groundwater over-abstraction in the Copiapó basin was the over-estimation of aquifer recharge (4.85 m3/s) levels in 1987 by the DGA by almost 1 m3 per second (re-evaluated at 3.5 m3/s) (Bitran et al. 2014). These estimates were too optimistic as they considered the very humid period of 1980-1990 as a baseline data. A second major cause was that agricultural users pump water 8 hours a day during 4 months and therefore only used a fraction of around 20 percent of their water right, defined as the capacity of the well (Bitran et al., 2014; RedAgricola 2015). These agricultural rights came to be considered as not fully exploited, which allowed for more water rights allocation. The problem arose however when those rights were transferred to mines, which would pump groundwater permanently. Likewise, consumption of water was calculated on the basis of a return flow (to the river and to the aquifer) from agricultural use, but those calculations remained based on conditions of gravity irrigation, failing to estimate the increase in irrigation technology efficiency (drip-irrigation), which generated "a systematic reduction in the recharge levels, since less excess irrigation water percolated into the aquifer" (Bitran et al. 2014: 858).[202]

[202] The allocation of groundwater rights in Chile is calculated according to the 'factor of use' which reflects the 'nature of exploitation of groundwater'. This means that the volume of water granted to users is calculated based on the potential total volume based on the recharge of aquifers as well as the use. This means that, for agricultural activities for instance, the total potential volume granted will not be effectively consumed as farmers would only use part of the volume allocated every year (factoring in the fact that they would pump groundwater 8 hours a day and not 24 hours, and around 4 months a year). This 'factor of use' allowed to estimate the percentage of real use of the resource by the DGA and grant around 5 times the volume used for agriculture (considering that 20 percent of that volume will effectively be consumed). This formula however led to the over-assignation of abstraction rights which could potentially be fully exploited or sold to other

The situation of the over-allocation of rights in the aquifer was assessed by the DGA in 1993 (Resolution No.193, 27th May 1993), which found a level of abstraction permitted 5 times that of the average recharge rate for the aquifer. Through that same resolution, the whole aquifer was declared a 'zone of prohibition' and new groundwater rights would not be granted (Montero Moraleda 2012). In 1994, however, the decision was modified and the 'zone of prohibition' was changed allowing for new groundwater rights to be granted in some of the sectors of the aquifer (the recharge area and lateral valleys of tributaries of the Copiapó)[203] (ibid.). This modification of the Prohibited area allowed for new wells to be drilled (with restriction being that new wells be located at least 35 km away from the river bed). In 2001, a new assessment by the DGA found that the conditions to maintain the 'Prohibition area' were not fulfilled in Sectors 5 and 6, which were re-designated as 'restriction areas', while sectors 1 to 4 remained as prohibition areas for new groundwater rights (ibid.).

The modification of the Water Law in 2005 (Transitory Articles 4 and 6) aimed at ending the situation of non-registered groundwater wells, giving the option to well owners to register their wells (provided that they had been drilled before 2004) with a simple declaration. The window to do this was opened by the DGA between June and December 2005 (with an additional 19 Mm3 of groundwater abstraction requested to be regularized). A further modification of the abstraction regime in the Copiapó happened in 2008 when the DGA decided to nullify 1.1 m3/s (equivalent to 34 Mm3) out of a total of 1.4 m3/s of water rights granted for the aquifer, as a measure to stop the decrease of aquifer levels in Copiapó after a new report had been released (Bitran et al. 2011; Montero Moraleda 2012). According to Bitran et al. (2011), the existence of the water roundtable as a negotiation measure helped enforce this measure and prevent conflict (See next section).

Despite that, wells continued to be drilled in the Copiapó Basin as provisional groundwater abstraction rights continued to be issued in Sectors 5 and 6 of the aquifer (as they were only under restriction zones) and due to the existence of applications for rights dating from before the declaration of the prohibition zone in 1993 (Bitran et al. 2014). The DGA had to grant these rights by law provided that the requirements stated for the application period were met (ibid.). Additionally, the 2005 Water Law reforms included the provision to regularize rights for those well owners who had carried out investments and exploited aquifers prior to 2004 (ibid.). Some of these rights according to Bitran et al. (2014) ended up being granted as provisional rights after 2006 but in 2009 a law had to prevent the DGA to grant further rights as it would have represented the regularization of an additional 1 m3 per second of groundwater abstractions (as provisional rights; provisional rights can be transformed in permanent rights five years after being granted). Based on what has been calculated as the available groundwater for each of the sectors, the DGA (2009) study on the integrated management of water resources in the Copiapó Basin established that the agriculture sector had been granted 1.9 times the available volume whilst the mining sector had been granted 2.9 times the available volume.

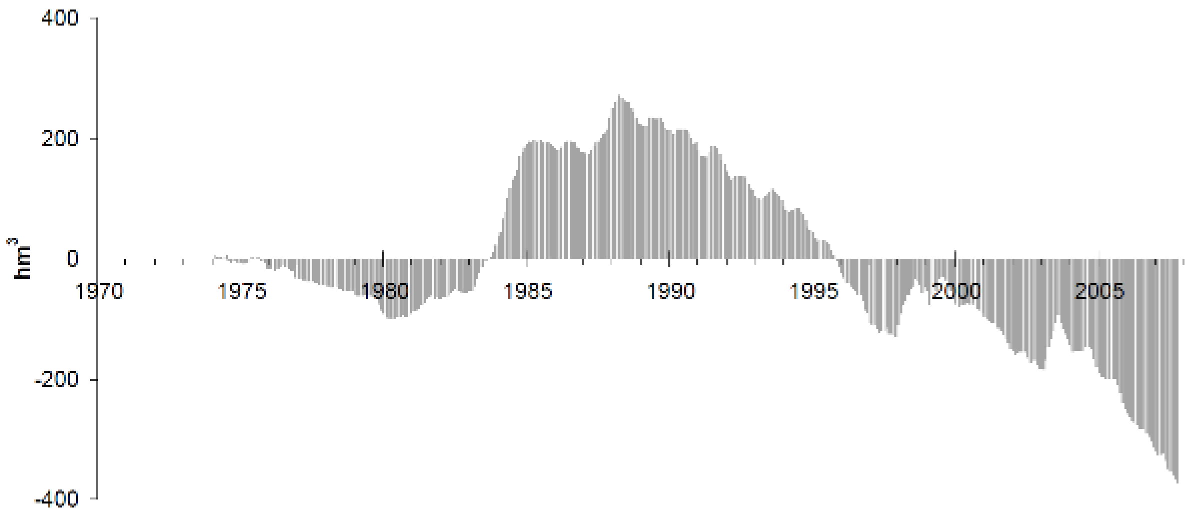
In 2003 a regulation by the Atacama regional office of the DGA sought to regulate and control all groundwater abstractions by demanding the installation of water meters in wells (DGA 2009b). Due to the lack of funds, logistical capacity, and staff, the program was cancelled and then re-

users. It also represents a problem if groundwater abstraction rights for agriculture are transferred to other activities (such as mining operations) using higher volumes of water (closer to the full allowed volume and for longer periods of time) (Burt 2008).

[203] This was justified in 1994 through Resolution 232 following new studies which suggested that the infiltration levels and recharge from these lateral valleys and affluent rivers to the aquifer were negligible beyond 35 km from the Copiapó riverbed as well as the long delays it took for groundwater to reach the main aquifer (recharging only 'in the long term' the groundwater volume found in the aquifer).

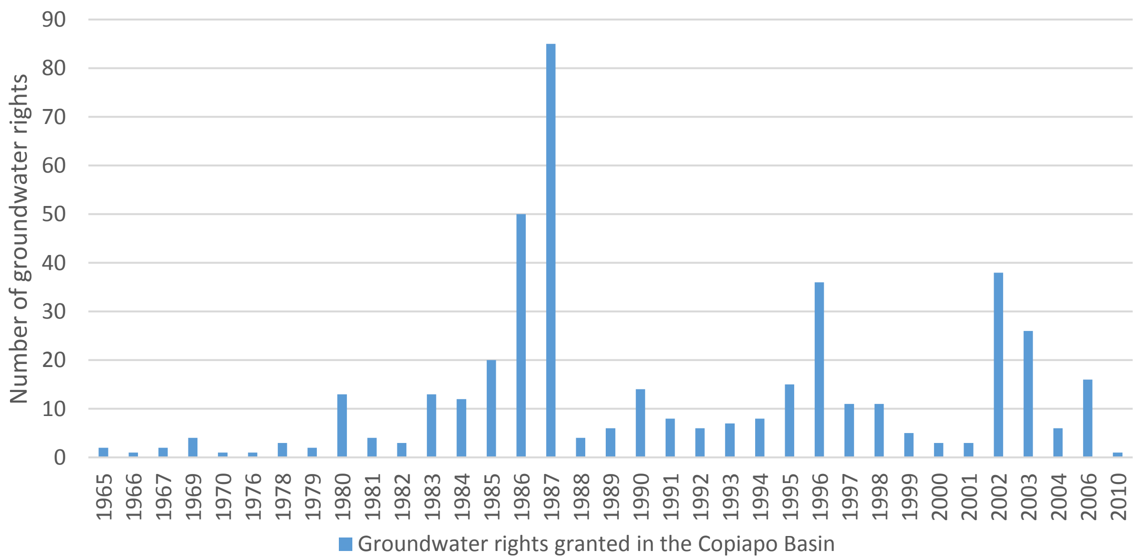
launched in 2009, this time only targeting the largest groundwater users (14 users with more than 300 litres per second of abstraction capacity granted) (ibid.). Following the continuous over-abstraction of groundwater since the late 1980s, the deficit of the aquifer in 2007 reached 360 Mm3 (DGA 2010). By 2010, 17.76 m3/s (560 Mm3) had been approved (92.7 percent of the total number of rights) (DGA 2010). Of that volume, 56.7 percent corresponds to groundwater for irrigation, and 17.2 percent for the mining sector (ibid.). Estimates of illegal groundwater abstraction represent according to the DGA (2009) 1 cubic meter per second. By 2012, the Water Directorate had granted 440 groundwater rights (as permanent and temporary rights) representing 19.6 m3/s (611 Mm3).

Figure 89. Variation in aquifer storage levels in the Middle and Lower Copiapó River Basin (Sector 4 to 6)



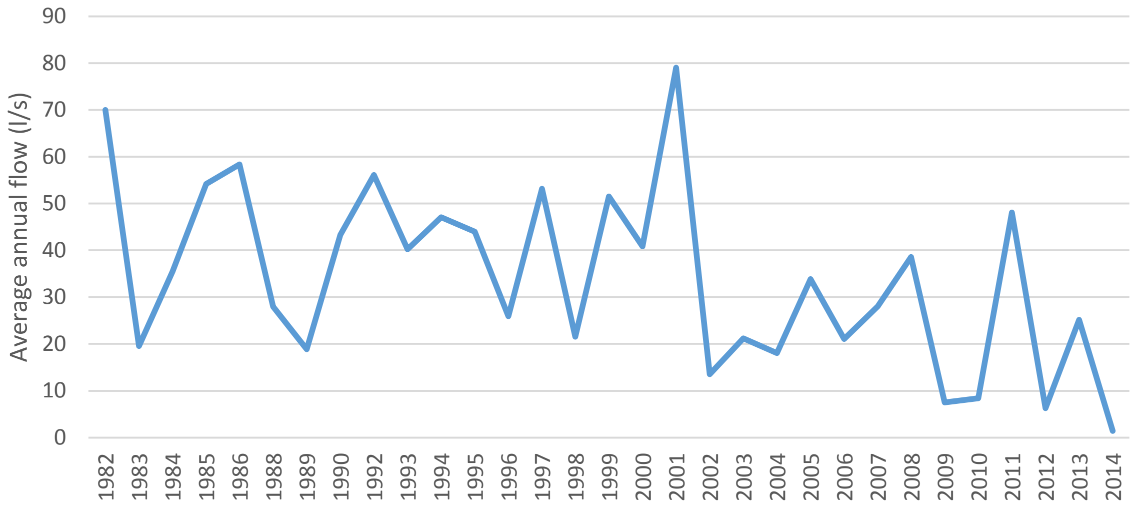
Source: DGA 2010.

Figure 90. Number of groundwater rights granted by the DGA in the Copiapó and groundwater abstraction levels



Source: Based on data from DGA 2012 and Montero Moraleda 2012.

Figure 91. Average annual flow granted for new surface and groundwater rights in the Copiapó basin



Note: data for 2014 only includes values for January and February.
Source: Based on data from DGA.

2.2 Groundwater management and allocation conflicts in the Copiapó River Basin

There is strong competition for water resources in some areas in Chile between the mining sector and agriculture. Additionally, the drinking water supply of the two main cities in the region, Copiapó and Tierra Amarilla (adding up to around 143,000 inhabitants), solely comes from groundwater. Mining started in Copiapó in 1832 with the finding and abstraction of silver, causing the region to develop quickly and the city becoming the mining capital of Chile (DGA 2009). During the first half of the twentieth century however, mining activities declined with the development of other areas in Chile. The construction of the Lautaro Dam in 1938 and the steel foundry of Paipote in 1953 initiated a second phase of development for the region (ibid.).

In the Copiapó River Basin there are currently 64 mining operations in total and 34 mineral production plants (with 26 operational in 2004) (Montero Moraleda 2012). Copper mining is currently carried out by one main company (Minera la Candelabria). There is also gold mining with two main companies exploiting two sites (Minera Mantos de Oro and Minera Can-Can S.A.). Despite the fact that it is known that mining companies have been buying water rights from local users in order to ensure the supply of groundwater for their activities (Godoy 2010), Bitran et al. (2014) stated that it is not possible to assess how many water rights have been purchased through the market by mining companies from individual users. Mining companies are willing to pay up to USD 2 per m3 (compared to agriculture willing to pay USD 0.2 per m3) (Bitran et al. 2011). The major problem has come from the fact that mines buy wells which are used at approximately 20 percent of their capacity and then use them continuously, greatly increasing actual abstraction. Another problem is the 'agua del minero' practice, whereby mines abstract large quantities of water when then extract mineral from deep open pits, quantities that are not computed (RedAgraria 2015). In terms of water resources, 42 percent of water rights for the mining industry come from surface water and 58 percent from groundwater (DGA 2009a). The conflict between mining and other uses is heightened as, given Article 110 of Chile's Mining Law, the owner of the mining concession has the right to use all the water found in the concession (Red Agricola 2015).

It would seem that some community members in Copiapó have made large fortunes selling water rights to mining companies. In 2009 for instance, two sons of a businessman and pioneer in agriculture in the area sold 100 litres per second and 80 litres/second respectively to the company Lumina Copper who paid 40,000 USD and 55,000 USD per each litre/second respectively earning them 4 and 4.4 million USD (Skoknik 2009). Some mining companies are also buying water rights in areas with limited restrictions and building pipelines to transport the water to their mining operation areas (Red Agricola 2015). Investigative journalist Arellano (2013a) published a story on businessman Isidoro Quiroga, a prominent and rich entrepreneur in Chile with at least 8 companies dealing in water markets in Chile, who apparently obtained more than 25 million USD between 2008 and 2013 with the sale to mining operations of water rights granted to him by the DGA in 2007 in the Atacama region – including the Copiapó Basin.

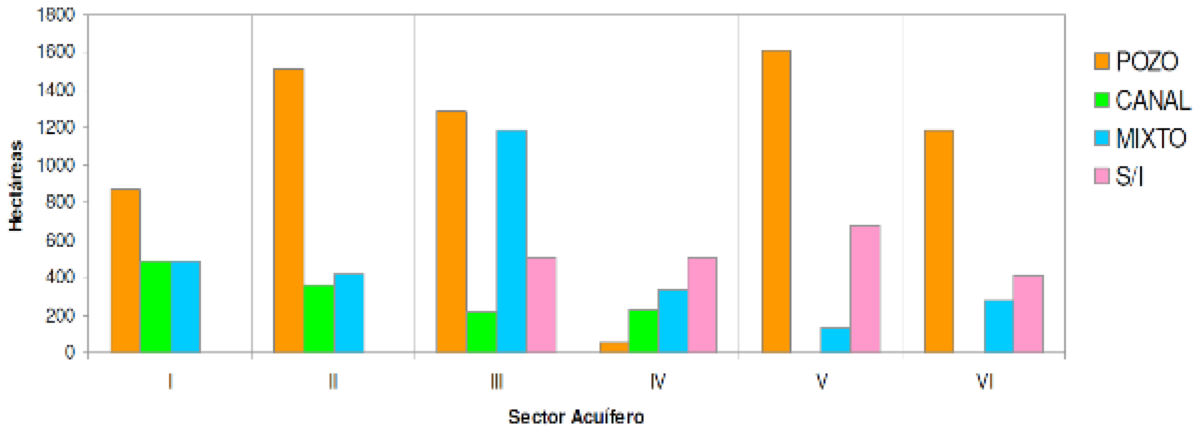
Grapes for exportation take however the largest share of water for agriculture. In the 1980s, Chile's military government implemented specific economic policies aimed at developing the country's fruit production and the cultivation of high-value and luxury crops for export, abandoning the agrarian reform initiated by the previous Allende government and moving away from grain production for domestic consumption (Bauer 2015; Jarvis 1994; Tinsman 2006). This transformation was done through the re-allocation of land to medium-size growers (after having reversed the public expropriation of land from the previous government), state credits, and the transfer of technology from the USA (Jarvis 1994; Tinsman 2006). Multinational companies also invested in joint ventures in Chile helping to create vast agribusiness regions in central Chile (Tinsman 2006). This trend spread across the country and as a result agriculture in the Copiapó basin increased after the 1980s, driven by accessible groundwater resources and accompanied by a new mining boom in the 1990s and 2000s due to high world copper prices (Bauer 2015). The USA remains the largest importer of Chilean grapes although exports from Chile have resented a surge in competition from Peru (ODEPA 2013; USDA 2013). In terms of market share, the Chilean share of the grape export market as the first exporter represented 21.3 percent in 2011 (ODEPA 2013).

This development drove a surge in the demand of water rights (initially surface water). As these were already almost fully allocated, the DGA in the 1980s under the new Water Law began to grant large amounts of groundwater rights. There are currently around 12,700 cultivated hectares in the Copiapó Basin in 2,073 farms (DGA 2010). Grapes represent the main crop, with 71 percent of the cultivated area, followed by olive trees (10 percent) and vegetables (10 percent) (ibid.). In terms of irrigation technology, 87 percent of the area cultivated uses drip-irrigation (ibid.).

The high point in the water allocation conflict in the Copiapó Basin occurred in 2006 with the Pascua Lama Mining Project to be developed by a Canadian Mining Company. As a result of the pressure from the public opinion against the project and a continuous drop of the water table, the regional office of the DGA initiated a process of public-private participation among users through the creation of a 'water roundtable' (*Mesa del Agua*) in order to improve water governance and the sustainability of water resources (Dourojeanni et al. 2010). In the Copiapó, the different gatherings of the water roundtable organized sought to improve the efficient use of water resources (surface and groundwater) and come up with alternative water resources for the basin (e.g. desalination for the coastal areas). The water roundtables also sought to find a common understanding between water users (Godoy 2010). In February 2009, the Government nominated the Regional Director of Water (representative of the Ministry in the region) as the Executive Secretary of the water roundtable. Civil society members were represented in equal numbers as the representatives of the public sector and the private sector.

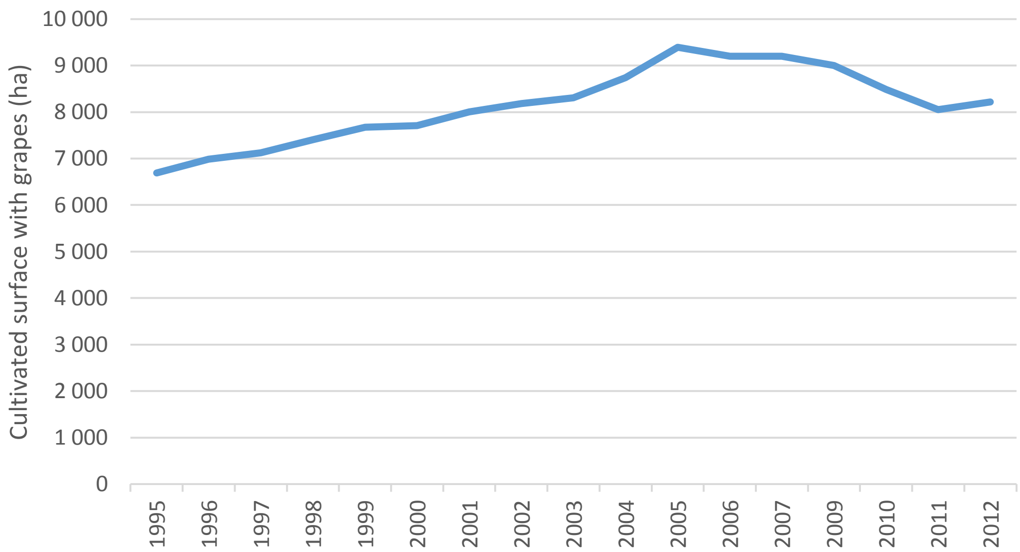
With the establishment of the National Strategy for Integrated River Basin management in Chile in 2007, the water roundtable in Copiapó became the participatory mechanism to implement the integrated water resource plan in the Basin (and becoming the River Basin Management Organization) (DGA 2009). The water roundtable for the Copiapó River however did not have independent funding (and financially depends on the Water Directorate and the National Water Commission).

Figure 92. Irrigated hectares according to water source in the Copiapó Aquifer



Note: In orange: well; in green: surface irrigation canal; in blue: both.
Source: DGA 2009.

Figure 93. Cultivated area for grapes in the Atacama region, Chile



Source: Data from INE 1999, 2009; except for 2009 (DGA 2010); data for 2010 and 2011 includes table grapes only (ODEPA 2013); data for 2012 extrapolated from SAG 2012 and Agroexports 2014.

2.3 Groundwater regulatory problems in the Copiapó Basin

According to Montero Moraleda (2012), one of the main problems perceived by groundwater users in the Copiapó basin is the over-allocation of groundwater rights by the DGA following a lack of applicability and transposition of the Water Law to the reality on the ground of an arid river basin with over-abstraction problems such as the Copiapó. Additionally, the lack of resources and capacity to regulate and monitor as well as a poor level of enforcement of rules (rule compliance and fines were only enforced until 2009 by one member of staff for the whole Atacama region) by the DGA undermines its capacity and capability to implement the law (ibid.).

This lack of control by the DGA is however coupled, according to Montero Moraleda (2012), with the freedom that users have according to the Water Law to modify and increase their groundwater use once the right has been granted (according to the 1981 Water Law). For this author, this seems to be the main institutional reason for the over-abstraction of groundwater. The change in regulation in 2005 seemed to aim at changing this rule as it set up maximum (volumetric) abstraction levels for granted groundwater rights. The need to increase the regulatory power of the DGA clashes however with the initial spirit of the Water Law, which granted private rights to water users and established an almost fully private system of water abstractions and exchanges of rights via the market, leaving transaction of water rights outside of state control (ibid.).

A lack of clarity in the groundwater granting process and the need to regulate historical abstractions according to the law fueled the increase in groundwater rights (Bitran et al. 2014). This process was also followed by poor information and contradictions. The legal imbroglio and several backtracks from the DGA contributed to this confusion over the years. The DGA's contradictory policies during the 1990s and 2000s did not improve this lack of legal clarity as they opened and closed several times the process of granting rights.

When the aquifer along the basin was divided into 6 sub-units (each one with its separate administration but bearing no geological sense), rights were granted without taking into consideration the basin's connectivity. The lack of staff and resources to monitor aquifer levels and enforce groundwater use and review water transactions also complemented the poor regulation by the DGA (Bauer 2015). A rigid legal framework of water rights did not leave much room for adjustment in view of the changing aquifer conditions (Bitran et al. 2014). The reform of the Water Law in 2005 did not bring an appeasement of water conflicts during the first decade after its approval (Bauer 2015). Conflicts concerning "property rights and regulatory governance in water, energy and environment have become a chronic and highly visible problem in Chilean political economy" (Bauer 2015: 1).

Conflicts arising from the over-allocation and over-abstraction of water resources in Chile are not limited to the Copiapó Basin. In the La Ligua River Basin south of the Copiapó, agricultural expansion and increasing groundwater use have also become a contentious issue amongst farmers (and in particular established large farmers) (Budds 2009). The majority of requests for new water abstraction rights have been submitted by large and smaller commercial farmers with the economic means to submit the applications (i.e. money to hire a lawyer to undertake the process) raising questions of access and procedural equity (ibid.). Having access to these groundwater abstraction rights also grants access for owners to irrigation subsidies from the state and thus further differentiation amongst users as access to formal structures by users without rights is being reduced (ibid.).

Additionally, illegal abstractions have proliferated without abstraction rights and also due to the inability and unwillingness of farmers to negotiate with the bureaucratic process of applying for groundwater abstraction rights (ibid.). The DGA decided to stop the procedure of granting water rights when it realized that there was an over-demand of rights based on the calculation of supply and demand of groundwater (ibid.).

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