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Chronicle of a Demise Foretold: State vs. Local Groundwater Management in Texas and the High Plains Aquifer System

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ABSTRACT: This paper assesses a case of co-management of groundwater between the state of Texas, pushing for the rationalisation of groundwater management, and local (mainly farming) communities organised in Groundwater Conservation Districts (GCDs), which are protective of their private groundwater rights. We first describe the main legal and policy steps that have shaped this relationship. The article focuses on the Texan portion of the Ogallala Aquifer in the High Plains aquifer system – an almost non-renewable system covering 90,000 km^2 and providing 95% of the irrigation needs in northern Texas. With this example, we further highlight the strategies of both parties, the different political, administrative, legal and regulatory complexities of the struggle around the definition of GCD-level aquifer management rules (the so-called 'Desired Future Conditions'). We end by reflecting on the power balance that has resulted from successive adjustments to a co-management form of governance, the advantages and disadvantages of a multi-layered state water governance system, and whether the de facto 'managed depletion' of the Ogallala Aquifer in Texas should be seen as an achievement or a failure.

KEYWORDS: Groundwater governance, co-management, groundwater policy, regulation, aquifer depletion, Ogallala, Texas

INTRODUCTION

From the heterogeneous geology of Texas, with its nine major aquifer formations and 21 minor aquifers (Lesikar et al., 2002), groundwater supplies 59% of the state's total water use (George et al., 2011). Around 79% is used for irrigation, with the High Plains aquifer system and Ogallala formation supplying 82% of that used to irrigate 1.8 million ha (George et al., 2011; Walton, 2013), from which a thriving agriculture and food production system have arisen (e.g. corn, maize, cotton, wheat). Indeed, the panhandle region of West Texas (the 26 northernmost counties in the state) is one of the most productive farming areas in the country. By the 1980s it accounted for 24% of the total value of exported commodities, and by 2011 it was producing 25% of US cotton (Weinheimer et al., 2013), with agribusiness representing US$5.8b in direct value in 2008-2011 and providing over 53,000 jobs (Amosson et al., 2012; Lehe, 1986).

A side effect of such dependence on groundwater is depletion – a phenomenon first recorded in the 1940s (e.g. Scanlon et al., 2010, 2012; Sophocleous, 2010; The Circle of Blue, 2014; The Desert Sun, 2015). The Texan portion of the Ogallala Aquifer has experienced more than 60 years of intensive pumping – at a rate of roughly six times its recharge (Mace, 2016). The early signs suggested an average decline in the panhandle area of up to 2.3 m between 1938 and 1946 (Broadhurst, 1946) and serious depletion (over 35 m between the 1950s and 2007) in some locations (Scanlon et al., 2012). Other aquifer formations in Texas, such as the Trinity Aquifer (a highly rechargeable system with different geophysical characteristics and management setup), saw declines of up to 243 m in some areas between the 1950s and 2000 (Lesikar et al., 2002).

Since 1965 Ogallala groundwater has been declared a non-renewable resource and treated similarly to timber and minerals under a special federal tax code, providing irrigating farmers tax depreciation allowances for groundwater declines (Hornbeck and Keskin, 2011b). A system of water rights rooted in the 'rule of capture' has also resulted in a situation of resource appropriation akin to the tragedy of the commons, whereby there is nothing to prevent landowners from abstracting the groundwater under their feet. In response, decentralization policies and community-based management of groundwater resources are seen by some (e.g. Megdal et al., 2017; Ostrom, 1990; Schlager, 2007; Schlager and López-Gunn, 2006) as a potential solution to the resource depletion and mismanagement suffered by users. They believe a collaborative system to be better placed to establish and enforce rules efficiently at the local level. However, as this paper will examine, the case of Texas shows that due to its particular context, the state has been forced to intervene, having to juggle with decades of population growth, increasingly competing demands, droughts, resource depletion, and perhaps most importantly, a policy platform premised in private property rights (Kaiser, 2006).

This led to a co-management situation between local users and the state, in which the responsibilities for allocating and using resources are shared by several parties with varying degrees of organisation and devolved powers (Conley and Moote, 2003; Plummer and FitzGibbon, 2004). In this paper we assess the boundaries of such groundwater co-management by the state and users (organised into Groundwater Conservation Districts) in the Texan portion of the Ogallala Aquifer. We look at whether effective synergies are created or not by the continuous adjustment of interactions between local groundwater users, legislators and administrators in an attempt to establish general rules for the management of groundwater resources.

We examine the many layers of management established by the state and the resulting multi-layered governance system (Ostrom, 1972 in McGinnis, 1999). This is an organisational structure where multiple centres of decision-making operate with some degree of autonomy but are mutually organised and related to one another under a common system of rules (Ostrom V., 1999, Ostrom E., 2005). These relationships are expressed in the form of multi-level, multi-purpose and multi-functional units of governance existing across fragmented and nested jurisdictions, hierarchies and institutions within a social system. Under polycentric systems, constituent groups have the ability "to solve their own problems based on options that are institutionally enabled in a self-governance regime" (McGinnis, 1999 in Araral and Hartley, 2013: 5). Polycentric governance can be concomitant to the design and development of decentralised forms of government and the devolution of environmental governing authority to local communities but also a characteristic of a more complex mix of overlapping institutions at multiple scales (Tam-Kim-Yong et al., 2003). We use Texas as a case study to explore the workings of polycentric governance in order to establish whether the putative failure of the state to regulate groundwater abstraction is related to the intrinsic limitations of such governance mode, which we aim to identify.

We begin by focusing on the historical, institutional and local political factors that undergird groundwater management in Texas, reviewing the evolution of the regulatory tools used to manage abstraction until the 2015 state legislative session. These revolve around the planning and management activities of Groundwater Conservation Districts (GCDs) – the basic groundwater management unit in Texas. Using the case of the High Plains and Ogallala Aquifer we explore the patterns of groundwater governance in further detail, before examining the different management practices developed by the GCDs while establishing their Desired Future Conditions (DFCs) and state-wide surface and groundwater planning. We then discuss the constant friction between the central agencies pushing for greater control and regulation and the local communities trying to protect their private rights and autonomy.

The paper concludes by suggesting what we can learn from these examples of co-management, with their multiple layers of governance, in terms of groundwater management policy in the particular political and hydrogeological context of Texas.

GROUNDWATER MANAGEMENT LEGISLATION IN TEXAS

From the rule of capture to the creation of GCDs

The rule of capture lies at the heart of groundwater management in Texas. Adopted in 1904 by a Texas Supreme Court ruling, it granted unlimited rights to withdraw any groundwater found beneath the owner's land without any permit to drill or pump (Hutchison, 2006; Smith, 2003). Due to the competition this created, and concerns over excessive abstraction from the Ogallala Aquifer, the need for groundwater management became the subject of much debate in the 1930s (Dupnik, 2012). Several unsuccessful measures to manage the situation included declaring groundwater the property of the state, guaranteeing the rights of those already making use of the resource and exercising control over future development (ibid). As a result, Texas became polarised between supporters and opponents of state regulation, as draft bills were filed along these lines or revoking the open-access regime and giving priority to municipalities and industries as opposed to the irrigators (Nachbaur, 2014; Teel, 2011).

In 1949 the Groundwater Conservation District Act was passed as a political compromise between the rule of capture and the need for groundwater management. Giving counties the responsibility for creating GCDs (Groundwater Conservation Districts) (Dupnik, 2012), anti-regulation supporters saw this 'middle-ground' solution as a lesser evil. A local high-plainsman declared: "I favour no control, but if we must have it, let it be local" (Dupnik, 2012: 6). The GCD Act left the state outside groundwater management, rendering state-wide conservation more difficult, and the ideology of individual rights over state control became entrenched in Texas groundwater management system (Somma, 1997).

Under the 1949 Act GCDs could be created by three different procedures: 1) by action of the Texas Legislature (usually introduced by a senator or representative). A procedure was established by the legislature to be confirmed by the county and a board was set up to allocate powers to the GCDs; 2) by landowners filing a petition with the Texas Commission on Environmental Quality (TCEQ, the Texan environmental agency) for the allocation of funding for the eventual GCD (Johnson, 2013); 3) by the TCEQ itself but only within a Priority Groundwater Management Area (see later) where users have failed to create a GCD or integrate an existing one (ibid).

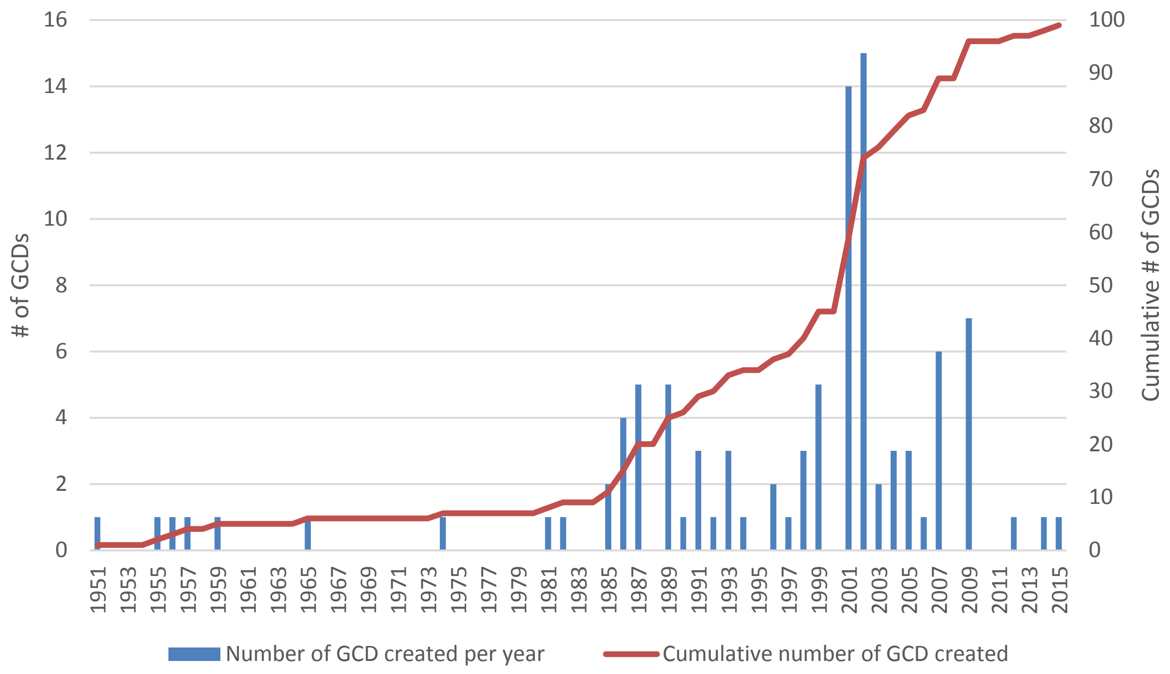
The four decades following the GCD Act saw the creation of only a handful of GCDs (Figure 1). It was not until the 1980s that GCDs began to be established more widely (19 in that decade alone). The GCDs did not follow the aquifers' geological boundaries but, aiming to protect landowners' rights, mainly respected county administrative lines. Although not the original purpose of GCDs, the significance of county-level groundwater management grew from a strong belief in private property rights, an aversion to broader interference (whether state or federal) and the prevention of groundwater export outside the area (Dupnik, 2012). Counties became the political and administrative unit dedicated to groundwater management following their approval by county commissioners' courts (for single-county districts) or the appropriate state agency for multi-county districts.

The 1990s saw another increase in the number of GCDs in reaction to attempts by the state to manage and conserve resources. Texas Senate Bill 1, passed in 1997 after the drought of 1995-1996, clarified and granted more regulatory powers to the GCDs by statutorily designating them the "state's preferred method of groundwater management" (Teel, 2011; Wythe, 2011). The powers included setting the requirements for abstraction permits, such as for wells abstracting over 25,000 gallons (95 m^3) per day, more restrictive conditions for new permits and well spacing regulation (Dupnik, 2012).

In 1999 the *Sipriano* court ruling questioned the rule of capture for the first time in 90 years. It highlighted the need for groundwater management, thus precipitating the creation of further GCDs.

During the 76th Legislature 30 GCDs were considered for creation against 44 established in the previous 50 years. Although in the *Sipriano* case the Texas Supreme Court ruled in favour of the defendants by upholding the rule of capture, the court's reflections blamed the same rule of capture for the lack of groundwater management in Texas. According to Dupnik (2012), the ruling also opened the door for future litigation, as disgruntled landowners affected by regulatory decisions could sue the GCD. As court cases can be lengthy and expensive, GCDs can be inclined to settle directly with users or relax regulation to avoid a protracted legal defence and legal costs paid from local taxes and fees collected by the district (Dupnik, 2012: 48).

Figure 1. Groundwater Conservation Districts created in Texas (1951-2015).



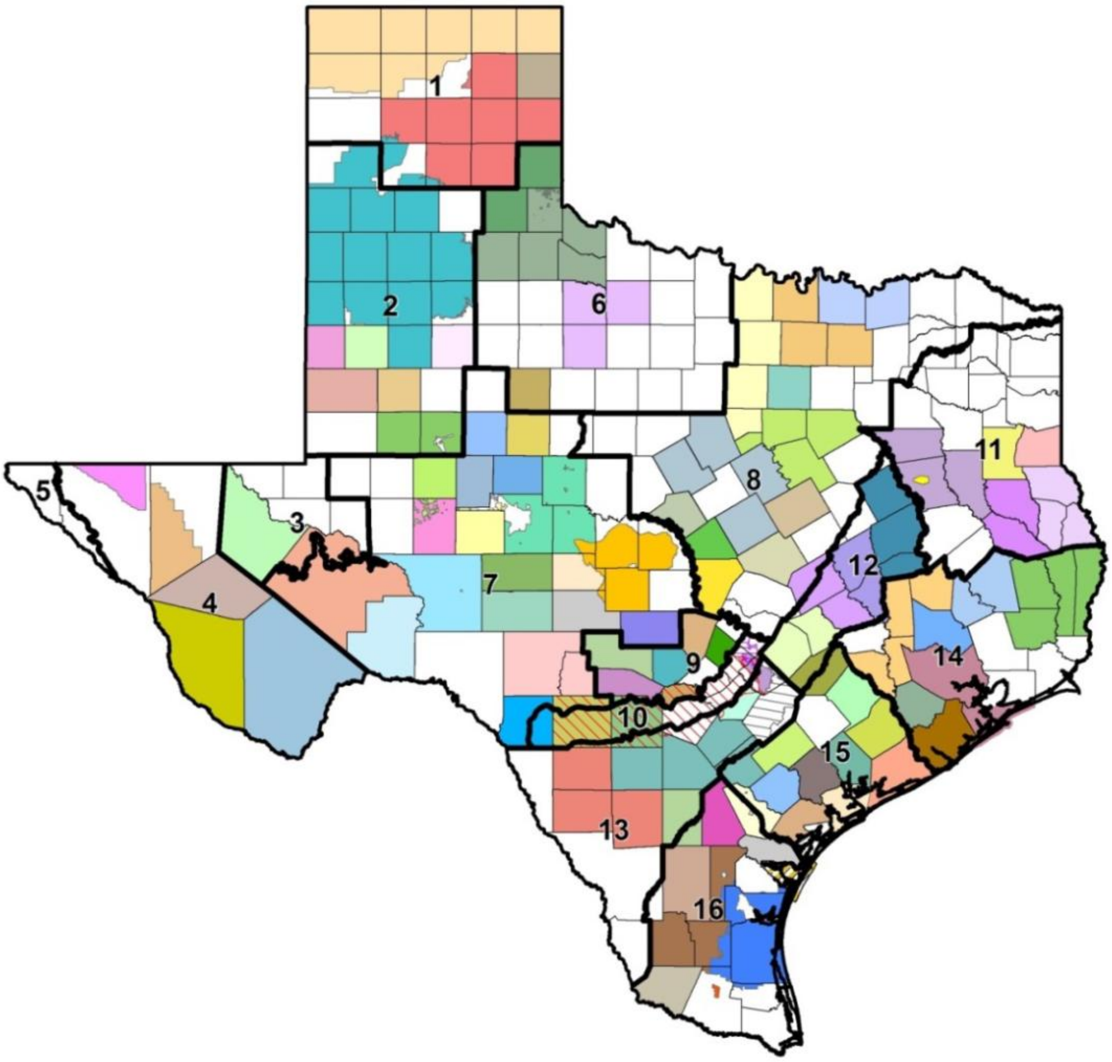
Source: based on data to 2009 from Dupnik (2012) and from TWDB (2010-2015).

Further legislation in 2005 and after

During the 2005-2006 drought that caused state-wide losses of US$4.1b (Henry, 2011), the Senate passed House Bill 1763, creating a 'profound change' in how groundwater availability is determined in Texas (Mace et al., 2008: 1). The Texas Water Code of 2005 further controlled groundwater management, granting the GCDs the power to conserve and protect the resource. This included non-mandatory provisions, such as well spacing, regulatory enforcement by courts, inventories of groundwater wells, annual taxes to cover district expenses, and management plans (Teel, 2011).

The bill required GCDs within a Groundwater Management Area (GMA) (see below) to collectively establish 'Desired Future Conditions' (DFCs) – i.e. the state of the aquifer to be achieved within a set timeframe (more on this later). The bill also intended to establish regulation for well permits so as to control abstraction (in line with the DFCs). With the majority of districts previously not having had overall caps on groundwater abstraction in place, the bill meant that, with members' agreement, GCDs could issue permits "up to the point that the total volume of groundwater permitted equals the managed available groundwater[1]" (Mace et al., 2008: 3). The bill also transferred the responsibility for overseeing the setting of DFCs to the Texas Water Development Board (TWDB). Within each of the 16 GMAs created by the TWDB in 2001 groundwater management plans had to be coordinated between the GCDs (Figure 2).

Figure 2. Main groundwater governance units in Texas.



Note: this map represents the GCDs in Texas per county. Each colour is an individual GCD. The counties represented in the same colour constitute one GCD. White denotes a county with no GCD. Bold lines and numbers refer to Groundwater Management Areas (GMAs).

Source: Sunset Advisory Commission, 2011c.

The GMAs follow the main aquifer boundaries and membership is exclusively GCD appointees (usually the general manager or board president). The state was also authorised to introduce Priority

[1] Defined as "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" (Hermitte et al., 2015: 12).

Groundwater Management Areas (PGMAs) where a critical groundwater situation existed or was predicted within 50 years. If a study area is labelled a PGMA, the TCEQ can recommend the creation of a specific GCD (where none exists).

In 2011 Senate Bill 660 further strengthened the GCDs' role by making their representatives the sole voting members of the GMAs and giving them a representative in the Regional Water Planning Groups (RWPGs), whose diverse membership of around 22 included municipalities, agriculture, industry and utilities. As the TWDB, the 16 RWPGs create 50-year plans for infrastructure and water supply needs (from both surface and groundwater) and develop a list of water management priority projects eligible for TWDB funding, known as the State Water Plan, to meet future water demand in each river basin (e.g. new reservoirs and pipelines) (Sunset Advisory Commission, 2011c). The RWPGs have different boundaries from the GMAs. According to Dupnik (2012: 802), by enhancing GCDs' power, this bill relegated the GMAs to mere "lines on a map", facing the increasing importance of local management by the GCDs.

In 2015 Senate Bill 1101 addressed regional water plans, allowing the inclusion of those areas not belonging to a GCD in the Regional Water Planning Group. The bill stated that RWPGs could determine groundwater supply for planning purposes in areas without a GCD (the supply having to be compatible with the DFCs of the GMA concerned), thereby closing the loophole created by counties without a GCD.

The local reality of GCDs in Texas

GCDs are very diverse. Only 174 of the 254 counties in Texas belong to a GCD and there are currently 99 GCDs in Texas (97 confirmed as of July 2015), with 62 single-county GCDs (Figure 2). The increase in single-county GCDs reflects a political landscape that favours the concept of local control, in contrast to earlier years when multi-county GCDs were created to manage significant portions of aquifers threatened by over-pumping (Dupnik, 2012). This translates into a stronger influence of local politics and county governments over the development and running of GCDs (Kaiser and Phillips, 1998).

Many GCDs face operational and management challenges and are often unable to fulfil their responsibilities due to inconsistent budgets and limited income from fees or taxes (Brock and Sanger, 2003). This leaves them prone to political control and affects their ability to maintain operations and sometimes to meet their statutory requirements. Although responsible for controlling improper drilling, excessive abstraction and direct contamination, it is difficult for the GCDs to enforce the law, as districts lack the financial capacity for legal battles or to risk bankruptcy from litigation against a private user contesting management rules (GCD 1, 2014). As groundwater is considered a private property right, users can sue or challenge the District Board if they feel the GCD is either lowering the value of the property or over-regulating the use of groundwater.

Rather than weakening the rule of capture in Texas, the GCDs complement it, as their creation was a pre-emptive move to limit state control of groundwater as much as a compromise between conservation efforts and landowner demands (Lesikar et al., 2002). Even where a GCD exists the rule of capture protecting private abstraction rights still applies if the district chooses not to regulate well spacing or set pumping limits (ibid). GCDs must adopt a well registration programme, with exemptions for small volumes, but the installation of meters "is a local option" (ibid). While most GCDs do not require it, "many consumers opt to install meters for business and management purposes" (ibid). However, with the recent legal changes, pumping volumes per se are not "the vector for potential enforcement by the state; it's the DFC" (TWDB, 2015), and compliance with DFCs can be assessed either by the remaining volume in the aquifer, aquifer drawdown, spring flows or reduced pumping levels.

The degree of enforcement of groundwater management rules at the local level is hard to assess. The Texas Railroad Commission's enforcement of water quality in the oil and gas sector could be used as an equivalence as it includes groundwater protection (Sunset Advisory Commission, 2011a). The Sunset Advisory Commission, a legislative body with a mandate to identify and 'eliminate' inefficiency in state agencies, reviewed the Railroad Commission and concluded that it rarely carries out enforcement, creating minimal deterrence to possible contraventions (less than 4% of violations on file are followed up for law enforcement) (Sunset Advisory Commission, 2011b).

Attempts at coordinated regional management: The Desired Future Conditions of groundwater in Texas

Establishing DFCs

As mandated by House Bill 1763, since 2005 each GCD in Texas is required to participate in joint planning in at least one GMA, adopt Desired Future Conditions (DFCs) for all relevant aquifers and submit them to the TWDB. DFCs are policy expressions of what a GCD and its GMA want the aquifer to look like in the future.

DFCs are required 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). DFCs are essentially policy decisions, establishing a planning horizon of permissible groundwater drawdown and how to get there. In establishing a set of DFCs, GMAs are statutorily required to take into consideration nine factors identified in the Texas Water Code. These include aquifer uses, hydrological conditions, annual recharge flows, impacts on spring flows and other variables, as well as the impact on interests and private property rights over groundwater (Porter, 2014). DFCs are voted via a two-thirds majority of GCDs in a GMA and are then legally adopted by the individual GCD.

When setting future aquifer conditions and corresponding pumping limits, GCDs often choose "DFCs that allow current levels of pumping or even larger amounts. (…) In general, GCDs try to avoid curtailment to stay out of lawsuits; however, DFCs that result in reduced pumping are also adopted" (TWDB, 2016). Once the DFCs are submitted to the TWDB, the board generates Modelled Available Groundwater (MAG) reports for each DFC, establishing the amount of water that could be abstracted on an average annual basis to achieve the DFC, ensuring that the independently submitted DFCs work together hydraulically for each individual district (Porter, 2014; TWDB, 2016). If the overall groundwater impact is greater than the GMA model found to be acceptable, or if a DFC is considered unreasonable or infeasible, the individual DFCs are rejected and will need to be reviewed. The DFCs in each GMA are voted on by GCD representatives (the only members to vote on DFCs), after which a revised DFC is sent back to each GCD. The TWDB uses modelling to assess each DFC as proposed and adjusts the pumping levels as required. GMAs also establish their own individual DFC and make sure that they are compatible with the other DFCs established at GCD level. GMAs must also ensure that MAGs are used as the mandatory basis for groundwater availability in regional water planning, as well as a key consideration for permits in individual districts (Porter, 2014). However, the TWDB is unable to effectively "mandate the districts or GMAs to make the changes" (Porter, 2014: 85; TWDB, 2016).

The allocated volumes for each DFC can differ within each county, since GCDs are able to declare an entire aquifer, or part of an aquifer, as 'non-relevant' (for example, where they are not delineated or the DFCs will not apply and MAG volume estimates are not available) (Hermitte et al., 2015). This system makes it difficult to avoid 'pumping crossflows' where there is aquifer interconnection between different GCDs, as well as in cases where GCDs want to adopt different DFCs. However, GCDs voting for a certain DFC in the GMA can vote out another GCD who would be opposed (and would then have to comply with the adopted DFC) (TWDB, 2016).

In areas of a GMA where there is no GCD ('white zones') "there are no regulatory mechanisms to prevent actual groundwater withdrawals in excess of availability" (Hermitte et al., 2015: 18-19). Such areas can be prone to free-riding behaviour by landowners, pumping as much water as they want, regardless of the DFC (Mace et al., 2008). Indeed, the threat of 'white zones' drove the board of one

GCD located near a county without one to approve a 'generous' 72-foot drawdown by 2070 in its DFCs, even though it had originally only wanted a 20-foot drawdown (GCD 2, 2015).

Appealing the DFCs locally

Stringent DFCs in certain counties have been fought by users claiming that their water rights would be worthless were they approved. Some local users also view the DFCs as the latest episode in the state's push towards centralisation (GCD 2, 2015). Users can appeal to the TCEQ over whether a GCD has rules to achieve the DFC and if the district is enforcing them (TWDB, 2016). If the commission upholds the complaint and decides that the rules adopted by the district "are not designed to achieve the desired future conditions, the Commission may (…) dissolve the district's board and call for the election of a new board, (…)" or even "dissolve the district" (Mace et al., 2008: 6). The legislation also allows GCDs to modify and revise the DFCs once every five years (Mace et al., 2008). This leaves room for internal conflict between members over the need for groundwater conservation (TWDB, 2016). As an example, in the High Plains Underground Water Conservation District new DFCs met with opposition from district members once the board introduced pumping restrictions and the compulsory installation of water meters. Members managed to have a new board elected, who appointed a general manager with "a very different viewpoint" and a more permissive approach, preventing any infringement of private property rights and avoiding the "slippery slope toward socialism" (Lubbock Avalanche Journal, 2014b).

In 2015 the 84th Legislature added new provisions to the Texas Water Code that modified the petition and appeal process through which users can challenge the reasonableness of DFCs (Lloyd Gosselink, 2015). The new rules shifted authority from the TWDB to the GCDs and, ultimately, to local courts (TWDB, 2015). Appeals against a GCD's final ruling on DFCs can be filed at a local district court with jurisdiction over any part of the GCD (ibid), meaning that the regulatory system can be opposed in court by individuals acting out of private interest and seeking compensation for a perceived breach of their rights. Such a mechanism would appear to significantly weaken the purpose and authority of regional and state-level groundwater management.

GROUNDWATER OVER-ABSTRACTION AND REGULATION IN THE HIGH PLAINS OF TEXAS

The Ogallala Aquifer

The presence of groundwater in the High Plains of Texas is due to the High Plains aquifer system – the largest in the US with 450,000 km^2 underlying parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. It supplies almost a quarter of the total water for agriculture in the US (Gurdak et al., 2007; McMahon et al., 2007) and includes various geologic units, with the Ogallala formation accounting for 77% of the system extent (Qi and Christenson, 2010). The Ogallala was formed by ancient runoff from the Rocky Mountains (to the east) trapped in sandy soils, gravel, clay and silt (Hornbeck and Keskin, 2011a). The Ogallala portion in Texas is essentially a non-renewable resource, covering around 90,000 km^2 and receiving less than an inch of annual recharge due to low rainfall, high evaporation and low infiltration that reaches the shallow subsurface only (de Brito Neto et al., 2016; Scanlon et al., 2010, 2012; Hornbeck and Keskin, 2011a). It is considered non-renewable based on the fall of the water table due to groundwater abstraction and its minimal recharge (Scanlon et al., 2010; TWDB, 2016).

According to Scanlon et al. (2012), 35% of the groundwater depletion in the Ogallala aquifer system happens in 4% of the land area (including Kansas and Texas). Texas accounts for 62% of the total depletion in the Ogallala Aquifer (ibid), resulting in a constant decline in groundwater levels over the last 60 years, in some cases more than 90 m (George et al., 2011). Indeed, since 1955 farmers have been able to apply for state compensation and receive depreciation allowances due to groundwater depletion; although this has created an incentive to pump, without suffering the consequences

(Hornbeck and Keskin, 2011b). In 2010 the amount of available groundwater[2] was 7.4 Bm^3 (ibid); however, abstraction is not uniform and areas with high pumping rates can face far more critical deficits. Historical trends showed a decline in the average water level in the Ogallala Aquifer of -12 m between 1950 and 2011 (McGuire, 2013). Estimates of the total volume depleted in the Ogallala system between 1950 and 2007 vary from 328 Bm^3 (Stanton et al., 2011) to 385 Bm^3 (Haacker et al., 2016), depending on the interpolation method. The southern part of the High Plains has been affected the worst, with a 75% decline in average saturated thickness since 1950 (ibid).

In the first half of the 20th century the dominant crops in the High Plains were wheat, alfalfa and sorghum grain, shifting to corn and soybeans in the 1950s (Brown and Pervez, 2014). The demand for corn as livestock fodder and more recently for ethanol production sustained this crop despite the increase in commodity prices in 2000 (ibid). Corn remains the predominant crop in the High Plains, accounting for 47% of the total irrigated area (ibid). The 2007 USA Farm Bill, encouraging biofuel production, provided significant incentives to grow corn all year round as a monoculture (Basso et al., 2013).

Groundwater management in the Texas High Plains: DFCs as 'managed depletion'

In the Texas High Plains, the DFCs approved regionally for each GMA establish different variation percentages for the saturated thickness remaining in the aquifer in 50 years. Different DFCs can exist for neighbouring GCDs as long as they are 'reasonable' and 'physically possible' but reasonable only to the GCDs in the GMA (TWDB, 2016). However, some GCDs will consider it 'reasonable' to pump groundwater and dry up the aquifer while others will not (ibid). The state "does not have a say in that" except for limited circumstances (e.g. protecting endangered species) and defers to the GCDs to deal with such issues (ibid), leading to "widely divergent management goals and requirements in and over the same aquifer" (Texas House of Representatives, 2014: 33).

DFC calculations are based on current groundwater storage and resource availability as determined by each GCD. Consequently, the main purpose of DFCs is that GCDs have collectively established management horizons: "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 the boards will be voted out to go in a different direction" (TWDB, 2015). One GCD member noted, "DFCs can be used by a district to drain an aquifer" (GCD 1, 2015).

However, another member of a GCD declared, "[DFCs] are supposed to be a management tool not a hard cap" (GCD 2, 2015). Although GCDs set their own abstraction levels and assume that users will make full use of their allocations, this is not necessarily the case (Porter, 2014). Well permits do not always correspond to groundwater pumping volumes. In theory, GCDs should use MAG volumes as a basis for the allocation of groundwater permits. However, different GCDs issue permits differently (e.g. considering correlative rights or historic use). Permits become symbolic of the landowners' right to groundwater: while not necessarily used in full they carry potential financial value (for example, if sold to a water utility).

This is illustrated by the North Plains GCD, created in 1955, which believes it has the measures in place to control and decrease groundwater abstraction as per the DFC. In 1995 new regulations aimed to establish an agreed annual decline rate based on a percentage of the aquifer's saturated material (North Plains GCD, 2017). Any use above this level would be investigated, and, if necessary, a strategic conservation area would be created (as per the North Plains GCD's management code). The GCD board would request users in that area to install meters and limit groundwater withdrawals to bring the area

[2] Defined as the amount of water from an aquifer that is available for use based on law, groundwater management goals and regulations, and planning group policy, rather than on safe yield (George et al., 2011).

back in line with the DFC (ibid). Following this procedure, and based on several depletion studies, the board determined that almost the entire GCD qualified as a strategic conservation area. Amending the regulations, in 2003 it stipulated that all wells install meters. Facing opposition from users due to the prohibitive installation costs, a general reluctance to report groundwater withdrawals and the fact that other GCDs did not require meters, it decided that the ruling would only apply to new wells. Groundwater withdrawals from existing wells would be estimated through data reported annually to the GCD and staff monitoring (e.g. by submitting electric or diesel consumption records, or centre pivot nozzle package specifications and operating hours, with margins of error of up to 20%) (ibid). In 2006, after a close vote, the GCD passed a groundwater production limit for irrigation wells of 1,850 m^3 per acre, the GCD and TWDB sharing half the installation cost. The GCD also operates a strong water conservation and demonstration programme. Albeit reluctantly, farmers accepted the board's decisions as its members belong to the farming community (ibid).

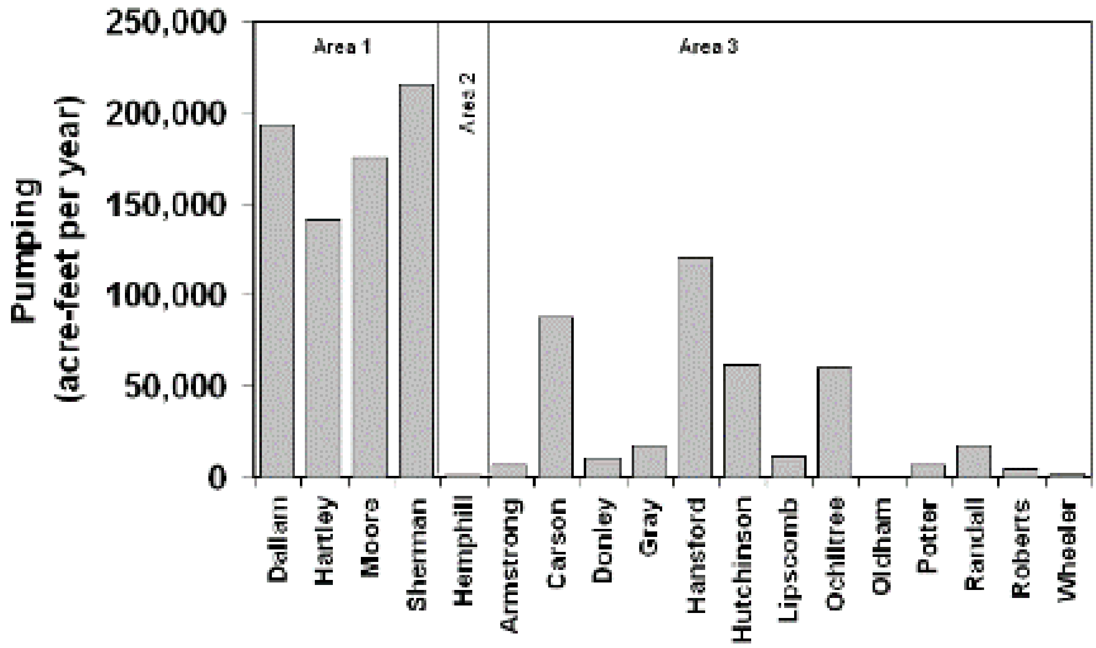
County-disaggregated data shows that the potential reduction in aquifer levels in 50 years' time can be substantial in certain areas. In the panhandle area (GMA 1) (Table 1) some GCDs set a target of 40% of the aquifer storage remaining in 50 years (40/50), while others set it much lower. The mismatch between aquifer boundaries and GCDs creates a situation where certain DFCs can be adopted at the aquifer level across a GMA (as a uniform average) but can also be designated separately according to an aquifer's subdivisions or the geographic area overlying an aquifer (such as a GCD) (Sunset Advisory Commission, 2011c). Dallam County – a single-county GCD, set a DFC of 23% of aquifer volume remaining in 50 years' time (TWDB, 2010) (Table 1).

Table 1. Summary of groundwater storage remaining after 50 years by area and county in GMA1

Area	County	% volume remaining after 50 years by county	% volume remaining after 50 years by area	% 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 3. Average historic groundwater pumping from the Ogallala and Rita Blanca aquifers in GMA 1 per county (1950-2000).



Source: TWDB, 2010.

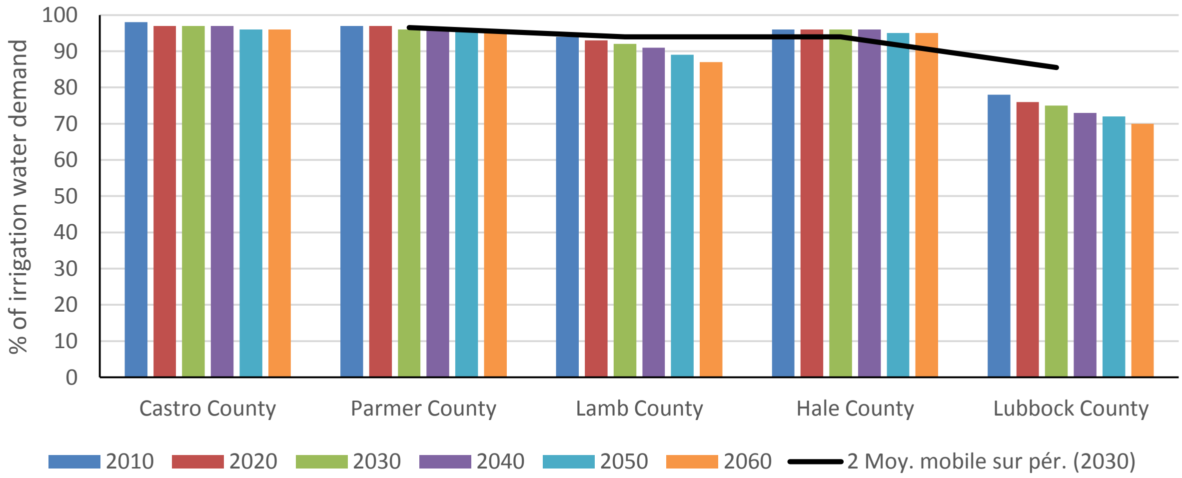
However, there seem to be discrepancies between the GCDs' estimates of current and future groundwater use and availability and the values provided by the Texas State Water Plan through the regional water planning process (Hermitte et al., 2015). State-wide groundwater availability as predicted by GCDs is 55% higher for 2020 than the total amount of groundwater resources established by the regional water plans for 2020 and 52% higher for 2060 (ibid).

According to Hermitte et al. (2015), the discrepancy results from 74 counties, mostly located in the northern panhandle but also in far west Texas and near the Gulf Coast, retaining a safety buffer for future needs and to maintain or potentially even increase abstraction. In addition, regional water planning groups have different timeframes from the GMAs and therefore use out-of-date data before the DFCs are approved (Hermitte et al., 2015). However, as Hermitte et al. (2015: 10) wrote, "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". This leads some GCDs to report higher groundwater usage levels to accommodate predicted groundwater demands.

Returning to GMA 1 in the Ogallala Aquifer, both the 50/50 (50% of aquifer storage left in 50 years) and 40/50 DFC scenarios impose pumping limits that require reductions in projected withdrawals. Following TWDB (2010) projections, under the 50/50 scenario water consumers would need to have begun reducing their withdrawals in 2014. The 40/50 scenario, meanwhile, requires reductions to begin in 2023. By 2060 the projected accumulated reduction in withdrawn groundwater would total 275 Mm^3 under the 50/50 scenario and 175 Mm^3 under the 40/50 scenario. However, in some areas the economically accessible groundwater already represents 50% of the total volume stored. Coupled with DFC levels in some areas aiming for 50/50, this results in the quasi-official endorsement of the total depletion of the aquifer (via the approval of the DFCs). In addition, the arduous task of actually controlling and reducing groundwater abstraction to attain an acceptable abstraction regime for the aquifer is often deferred to the future. Locally, counties are planning a (slight) reduction in groundwater supply between 2010 and 2060. This is observable in the High Plains Underground Water District (HPUWD, a multi-county GCD, whose creation in 1951 was the first in Texas) where reductions in total pumping levels projected for 2060 are postponed until years hence (Figure 4).

As a GCD board member put it, "we are doing controlled mining" (GCD 3, 2015); and irrigation looks set to maintain its level of water consumption for years to come, since DFCs seen as too stringent can be reviewed by a new board. DFCs are not really intended to reduce abstraction (TWDB, 2015). A source in the TWDB elaborated: "[t]here are some cases where DFCs have been set to honour current pumping levels and honour expected increases in pumping in the regional water plans" (TWDB, 2015). Thus, existing groundwater abstraction volumes may be considered the status quo baseline on which DFCs are based. As a TWDB staff member said, "the status quo of non-sustainable development is baked into current thought of groundwater management in Texas" (TWDB, 2015).

Figure 4. Percentage of irrigation water demand over total water demand in the five counties with higher groundwater demand in the HPUWD.



Note: trend line illustrates a 2% moving average with 2030 as reference year.

Source: Based on data from HPUWD, 2014.

MULTI-LAYERED GROUNDWATER GOVERNANCE IN TEXAS

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

Groundwater and private property

Texas has seen legislative and management bottlenecks over the years caused by limits to the control of water by the state over private interests. Landowners' private ownership of groundwater was underlined by Senate Bill 332 in 2011 and further affirmed by the Texas Supreme Court in 2012 in the Edwards Aquifer Authority vs. Day and McDaniel (Collins, 2015). The ruling recognised the vested interest in groundwater underlying a property and laid the foundations for an increase in the economic value of groundwater, as compensation was established for users whose abstraction rights had been limited by the regulating authority (ibid).

Farmers generally view private property as sacrosanct, considering groundwater withdrawal restrictions and metering as "a real property rights violation" (Collins, 2015: 470). According to Emels et al. (1992), such views reflect the Texan ideology as enshrined in the legal system of private rights. Indeed, the Corn Producers Association of Texas declared: "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 (Texas House of Representatives, 2014). There is the fear that centralised state regulation would lead to one-size-fits-all management that would ignore local conditions (ibid).

While GCD pumping restrictions based on DFCs are pending, conservative users push to alter the makeup of the governing boards, by appealing to voters, in order to derail the process. In the High Plains Underground Water District those in favour of restrictions are labelled 'fascist', 'tyrannical' and unconstitutional due to government overreach: "we are all for conservation but not for confiscation" (Texas Tribune, 2013; Baake, 2013). The High Plains Protect Water Rights Coalition (a local, non-profit organisation fighting the so-called unconstitutional and uncompensated government takeover of private groundwater property) helped replace the GCD manager of 12 years along with four of the five members of the board with more conservative defenders of private property rights (Texas Tribune, 2013). As a result, moratoriums were granted and extended for those users who do not respect the pumping limits (as in the case of the High Plains Underground Water Conservation District in 2014) (Lubbock Avalanche Journal, 2013).

An incentive that was established to garner support for these measures is 'groundwater banking', whereby users may store unused groundwater from a wet year for the next (i.e. if a farmer receives enough rain to irrigate below the allocation limit, the difference can be carried over). However, years after having been approved, some farmers still consider any form of control intrusive and detrimental to their crop production: "we don't like them (…). We can't grow the number of acres we want to" (Lubbock Avalanche Journal, 2014a).

Since 1996 a small number of legal disputes have been recorded against GCDs (or specific board members), with nine cases up to 2014 and four between 2014 and 2016 (Miller, 2017), which are mostly brought by private water utilities or real estate developers along the urban-rural divide. A recent case involved Bastrop County and the Lost Pines Groundwater Conservation District, sued by Austin-based Forestar Real Estate Group, seeking a permit for 45,000 acre-feet of water annually from the Carrizo-Wilcox Aquifer (The Statesman, 2015). The GCD authorised the real estate group to pump 12,000 acre-feet per year, but Forestar waged a legal battle for the remaining 33,000 it claimed to be entitled to based on its initial purchase of pumping rights (ibid).

Consequently, House Bill 3163 (2015) sought to amend the Water Code so as to protect public servants from personal intimidation or legal threat arising from disputes and a 'charged [political] atmosphere' (Miller, 2017). Their exposure might constitute "a prior restraint on the faithful performance of a director and may even have a chilling effect on the willingness of citizens to serve as directors" (ibid). Individual board members are now immune from any suit and are not liable for official votes or actions. The GCD as an organisation remains subject to legal contestation.

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

Over the years groundwater regulation has 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 to manage and protect groundwater resources. This generates an intrinsic and continuous tension between the state, aiming to retain command-and-control powers and their political support base, and local authorities and users, with devolved powers and individual private rights.

The Texas Legislature took a decentralising approach to groundwater protection when it created GCDs and entrusted them with the management of the resource (Kaiser, 2006). However, while GCDs are the preferred method of managing groundwater according to the Texas Water Code, and are "political subdivisions of the State of Texas" (Russell, 2014: 1), they appear to be wedged between local landowning concerns empowered by the near-rule of capture and the push for more state-wide groundwater management. As more GCDs implement and enforce abstraction limits through the DFCs, more landowners can be adversely affected and take their complaints to their legislators and representatives in the capital, or sue their local GCDs.

Although the Texas Water Code (Chapter 36) gives GCDs a wide range of options for funding, their voting constituency chooses the system they see fit (some GCDs have no taxing authority and others have a lower than recommended ceiling for production fees). As the creation of a GCD often depends on "the area's political climate" (Brock and Sanger, 2003: 6), it can be vulnerable to private claims seeking to preserve local interests and sustain the self-limiting nature of districts and favour excessive pumping for short economic gain (Kaiser, 2006; Welles, 2013). The fear amongst users that the creation of a GCD would increase the cost of water and represent state interference in private property rights has been used to defeat local supporters of GCDs (Brock and Sanger, 2003). Conversely, defendants of decentralised groundwater management and GCDs hail their transparency following the 1967 Open Meetings Act of Texas for public bodies, which stipulates that all GCD business is open and public (Office of the Attorney General, 2014), supposedly serving to avoid management corruption and keep transparency in the GCDs management. Ultimately, however, as Collins wrote (2015), the core problem with local control is that it does not change the fundamental reality of groundwater: that it remains governed by relatively weak local regulatory bodies at risk of being thwarted by the very water consumers they are meant to regulate.

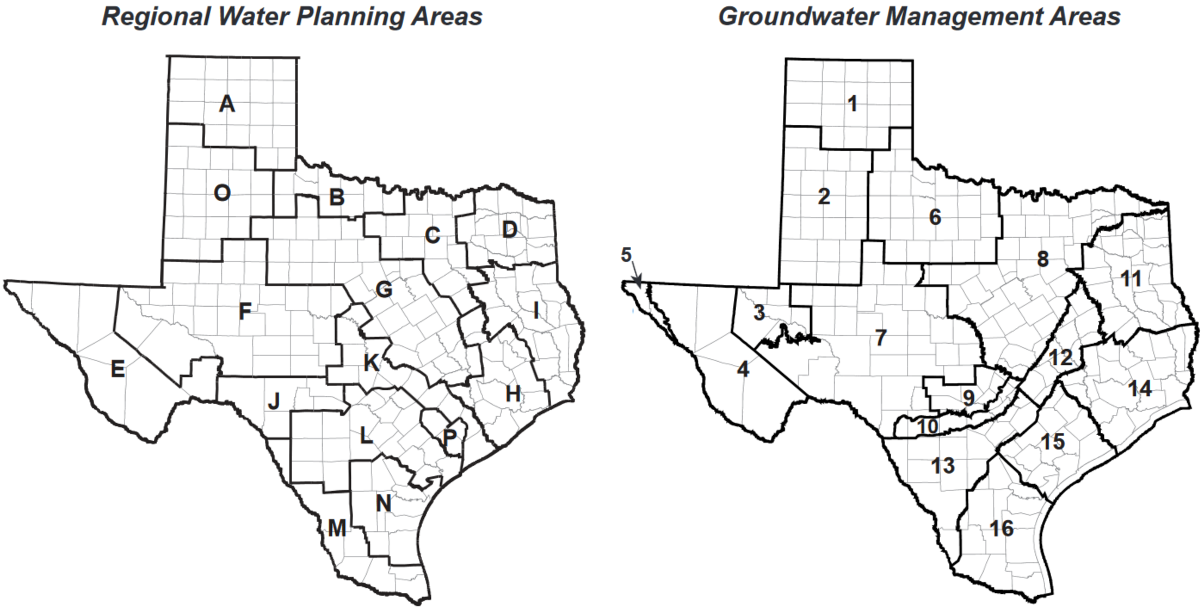
Thus, to date a rural-driven and private property-centred view has been governing groundwater law in Texas (Collins, 2015), and local management continues to serve as a counterweight to the centralising push of the state in what is perceived as slow central bureaucracy in Austin. For local users, this represents a cultural belief that a "decentralised system is the only thing standing in the way of rural areas and the urban areas sucking in all the people, votes and water" (GCD 2, 2015), while some emphasise that they "defend water management and keep it at the local level", "keep[ing] the state out of our business" (GCD 3, 2015).

The layers of groundwater governance in Texas

From the user to the GCD and above, the levels of government in Texas create a multi-layered system on which groundwater management and regulation depend (Figure 2). The interaction between market, state and private users brokers power, as each engages in politics to regulate and manage groundwater (Somma, 1997).

The system has problems, as the mechanisms of state rule operate at various scales and levels that generally do not match the district level. The mismatch between the TWDB's regional water planning areas and the Groundwater Management Areas, in particular, causes administrative complications and resource management misalignments (Figure 5). The 2011 Sunset Commission review of the TWDB described how the joint planning process through which GCDs are organised in Regional Water Planning Groups (RWPGs) to make decisions about aquifer future conditions affects the mandate of the TWDB to effectively conduct state-wide planning. This is because RWPGs "have no formal input in the amount of groundwater supplies available for meeting future water demands" (Sunset Advisory Commission, 2011c: 3). As for GMAs, they only include GCD representatives, with groundwater availability assessments "not fully vetted to determine impacts on water planning strategies and on the State's ability to meet future water needs" (ibid). Additionally, "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).

Figure 5. Boundary mismatch between regional water planning areas and groundwater management areas.



Source: Sunset Advisory Commission, 2011c.

The Sunset Commission finds there to be no standard procedure for questioning DFCs to ensure the submission process is fair, with clear resolution and due process for applicants (Sunset Advisory Commission, 2011c). Since GMAs and RWPGs have different scopes, there is a risk of overlapping jurisdictions and a lack of coordination between entities and plans.

Planning has been further hampered by inconsistent scope and the participation of GCDs in GMAs and RWPGs. According to the Sunset Advisory Commission (2011c: 25), the RWPGs' lack of participation in the DFC process undermined the TWDB and regional water plans "by tying the RWPGs' hands on what planning options or decisions are available to them and within their control. Specifically, the DFC 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". These findings were reflected in Senate Bill 660, which added as a voting member a representative of each GMA overlapping with an RWPG. It also took action regarding the alignment of DFCs and regional plans, stipulating that "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 GCDs for consideration.

Discussion

Much has been written about the groundwater crisis in Texas (e.g. Scanlon et al., 2012; Sophocleous, 2010; The Desert Sun, 2015). Yet, despite the wealth of studies, the intricacies of its groundwater governance and management systems often remain unpacked – entangled in a web of legal propositions and analyses. In the Ogallala Aquifer a combination of hydrological (near-fossil-aquifer conditions) and socio-political factors worked against the reduction in, or control of, overabstraction, creating a situation akin to that of the tragedy of the commons. For some, this justifies a state-level mandate to monitor, control and impose regulations to manage groundwater resources effectively. Others favour co-management by co-owners (Tietenberg, 2003) or market-based solutions. State groundwater regulation and laws, however, have had to contend with abstraction rights rooted in the rule of capture, a longstanding tradition of devolved governance at the county level, and the crucial importance of groundwater in the farming economy.

One view is that the state laws to manage groundwater resources created successive layers of regulation and a complex system of legal texts and rules "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", resulting in a "disjointed approach to water conservation", according to Porter's (2014: 18) severe judgement. GCDs are seen as belonging to landed interests as a check on potential state/federal regulations. The GCDs' primary objective to protect individual landowners' 'groundwater rights' is deeply ingrained in the concept that land and private property lie outside the scope and reach of the state (Dupnik, 2012). In sum, "districts have been formed to tell the state 'yes we got it', here is our fence, stay out of it" (GCD 3, 2015).

The districts' authority to enforce regulation, as backed by the courts, is rarely used. The judiciary is not its preferred option, solutions usually being worked out with landowners directly (ibid). Rules are applied lightly within a system that remains 'user-friendly' and with fearful suspicions of future state meddling and curtailment of private rights. A number of GCDs continue to have limited technical ability and lack financial resources, in particular to face legal challenges from their own members, and rely instead on persuasion and the ability of its staff to alter social expectations about groundwater use (Somma, 1997). The decentralised nature of GCDs also makes them vulnerable to conflict, being politically co-opted and electoral manipulation by local interests favouring unsustainable pumping and economic gains (Porter, 2014; Welles, 2013). Thus, it would seem that the purpose of GCDs is still "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). They have limited power for a reason but in contrast to their dominant position in GMAs and RWPGs, which they built up by lobbying for ad-hoc state legislation and where they can largely control and challenge attempts by the state to enforce constraining measures. The judiciary itself has never come to the point of drawing a 'bright line' between what constitutes a taking (i.e. the taking of private property for public use without just compensation) with some possible compensation and what does not (Mace, 2016). Court cases remain a Sword of Damocles over regulation efforts.

An alternative view is that democracy and decentralised management are about letting people decide their fate locally and that groundwater users are doing just that by collectively establishing their DFCs. Regulation by GCDs was intended to prohibit excessive or wasteful local depletion while not constraining production, especially if people did not want it (Emels and Roberts, 1995). If over a third of a GCD members agree to exhaust water resources by a certain time, they can block any restrictive moves and impose their collective position. If neighbouring GCDs prefer to be more conservative, they must either accept that a portion of 'their' water is siphoned off by their neighbour or adopt a similar policy. The state is not supposed to dictate what 'sustainable' or 'rational' management means. Its duty is to ensure that district-based DFCs and management are made compatible with objectives set up and shared at the GMA level, and then with state-wide surface/groundwater supply planning. It has gradually brought some (hydrologic) rationality through a relative reconciliation between county, GMAs and Regional Water Planning Area boundaries and processes. The multi-level state governance structure, with actors such as the TCEQ, TWDB and various aspects of the judiciary, is the result of a historical 'muddling through' rather than concerted organisational optimisation for resource management.

The rule of capture and respect for private property do not, therefore, imply a total lack of state involvement, and governance is exercised at different levels, instilling a "slow transition towards largerscale management" (Dupnik, 2012: vi). The central objective is to preserve this public 'private good' by disallowing wasteful use, raising awareness, proposing management tools, restoring coherence to the planning of surface and groundwater resource use (through the GMAs and RWPGs), establishing a framework wherein scientific data assists local decision-making, notably in agreeing DFCs. Given the absence of special conditions, such as those drawing state interventions in the Edwards Aquifer (Endangered Species Protection Act) and Nebraska (interstate compacts), there is little scope for either state or federal control in the Texan part of the Ogallala Aquifer, where modified return flows would not have critical environmental consequences.

And what of the local users' position on the future of the resource? Have they, or should they have, an interest in its preservation? In the words of one, "I want the young generation to have it for the future" (GCD 3, 2015). However, many refuse to see anybody's right to pump groundwater curtailed (GCD 2, 2015) and even "disagree with permits" altogether (GCD 3, 2015). There is little information on the factors that influence landowners' views of the future, but these are likely to include the prospect of offspring taking over the farm, perceptions about the future of agriculture and subsidies, alternative land use and particularly the ability to sell land to urban developers (Somma, 1997). One key factor, often overlooked, is having the depreciation of land value due to groundwater depletion reflected in federal tax returns since 1965 (Mace, 2016).

Is 'managed depletion' the ultimate goal and current policies increasingly successful in achieving it? Legal decisions are not immutable; they reflect changes in societal values as well as the distribution of political power and the rules of the game could change again. In the late 19th century it was thought that artesian wells were "an inexhaustible supply of water" and as it was dumped from the wells around Dallas into the Trinity River the city was transformed into a "seaport town" (Mace, 2016). It was a status symbol at the time to own a well and leave it constantly flowing (ibid). Perceptions have changed, to say the least, and could change again with a new generation of farmers. Power could also shift. It is interesting to note that Texas revoked the rule of capture in two coastal districts undergoing land subsidence. The politically powerful urban interests were able to override the few large, commercial groundwater users and have the law rule in their favour. Future game-changers could include growing urban demand, the impact of fracking on groundwater resources and shifts in agricultural markets.

With very limited recharge of the aquifer, the definition of 'sustainability' in the Texas High Plains remains elusive, since limiting abstraction to a level close to the recharge or to some 'hypothetical safe yield' would be tantamount to discontinuing agriculture. In a situation akin to that of a fossil aquifer, 'rational' management is believed to be a regime of abstraction that sustains existing economic activity over a well-defined period of time, while strategies are devised to manage its phasing-out (Foster and Loucks, 2006). Notwithstanding the constantly evolving quantitative understanding of the implications of abstraction, there seems to be little reflexion on 'what comes next'. The current system of DFCs for 2060 typically involves reductions of 40-50% in aquifer storage, but what is economically exploitable and whether water quality problems might appear are often unclear. Due to its very high rate of overdraft (~six times the recharge) the Texan Ogallala unsurprisingly confirms the general observation that in less stressed aquifers intensively exploited for irrigated agriculture (over)abstraction is hard to stabilise and impossible to steer back to a sustainable level (Molle and Closas, 2017).

As Kaiser (2006: 485) notes, Texas made "Faustian choices in allocating, managing and protecting its groundwater resources". The laissez-faire attitude enshrined in the rule of capture has, for a while, "minimised political conflict over governmental management and control of groundwater pumping" (Kaiser and Skiller, 2001: 251) but left Texas without effective enforcement and at the mercy of harmful over-pumping (Kaiser, 2006). Current arrangements largely perpetuate the depletion of water by irrigation and delay, or preclude, politically unpalatable decisions rather than seeking stricter management of the resource. Despite recognition of the negative effects of current laws and policies by legislators and managers, "a decentralised system is likely the only politically tenable groundwater management strategy in Texas" (Welles, 2013: 493). While Teel (2011: 76) sees the history of groundwater conservation districts in Texas as "the story of the public regulation of a private resource", regulation seems to appear through the cracks of these push-and-pull policies and concessions by the state, local authorities and users. In terms of management this is 'too little too late' but probably 'as much as possible' in the cultural and political setting of Texas.

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