AN INSIGHT INTO GROUNDWATER MANAGEMENT AND POLICY IN TEXAS

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
BSEACD	Barton Spring Edwards Aquifer Conservation District
GCDs	Groundwater Conservation Districts
GMAs	Groundwater Management Areas
HTGCD	Hays Trinity Groundwater Conservation District
TCEQ	Texas Commission on Environmental Quality
TESPA	Trinity Edwards Springs Protection Association
TWDB	Texas Water Development Board

I. GROUNDWATER MANAGEMENT IN TEXAS

Introduction

For over a century, groundwater resources in Texas have been allocated under the absolute ownership rights called the "rule of capture." Under the rule of capture groundwater is private property of the individual who owns the overlying land, providing the owner with the right to an unlimited capture of groundwater. This practice may lead to the depletion of the neighboring wells without any legal consequences for the person who is responsible. Moreover, the law does not offer any mitigation plan for those affected. The rule of capture not only affects reasonable access to freshwater for current and future generations, it is environmentally unsustainable. Thus, in addition to the human implications, the absolute nature of this rule undermines the lives of many non-human species who depend on groundwater resources in Texas.

Cultural and political complexities, including a strong culture of private determination of land usage in Texas, and the limited scientific knowledge about groundwater resources in the past created the ground for the adoption of the rule of capture. After a century, despite the advancement in science and technology, the cultural preference to privately "manage" the groundwater creates a huge barrier to the substantial modification or replacement of the rule of capture with a more sustainable alternative.

As early as 1920s, the occurrence of long drought periods and population growth have threatened the availability of freshwater across the state, which made policy makers wonder about the capability of the rule of capture to manage groundwater resources. As a result, in 1917, the Conservation Amendment was integrated into the Texas Constitution,

which authorized the Texas legislature to pass laws to protect and conserve natural resources across the state. In order to control and manage groundwater resources, the legislature introduced groundwater conservation districts (GCDs) in 1949 to improve the protection of groundwater resources and prevent the depletion of major aquifers. The legislative preference for local control has led to a "proliferation of GCDs that have been established along county boundaries rather than in accordance with the hydro-geographical boundaries of the aquifers for which they were established to manage" (Dupnik, 2012, 1).

The creation of GCDs and the groundwater management areas (GMAs), as a collaborative planning process for GCDs in a shared hydro-geologic area, have not in all cases resulted in effective conservation plans. The discord among the board members, lack of proper funding, and political influence of some stakeholders have created many challenges for the effective function of GCDs.

The purpose of this thesis is to gain insight into the root of the groundwater history, management challenges and the possibilities for improvement. By reviewing the literature, analyzing a case study and conducting interviews, this research aims to collect information regarding the current issues with the management of groundwater in Texas. The ultimate goal of this research is to formulate recommendations that can help policy makers improve the current management strategies toward sustainability of groundwater resources for future generations of all kind.

Definition of Groundwater by Texas Law

While the surface water rights in Texas belong to the state, the groundwater is governed by the absolute ownership rule, known also as the rule of capture. The rule of capture provides landowners with the right to pump an unlimited amount of groundwater, without liability to neighbors for damages caused by over-pumping, unless they have wasteful or malicious intentions (Canseco, 2008).

The Texas Water Code, sec. 35.002(5) defines the groundwater as "water percolating below the surface of the earth." According to the state's regulations, groundwater is defined as "[w]ater under the surface of the ground other than underflow of a stream and underground streams, whatever may be the geologic structure in which it is standing or moving." 30 Tex. Admin. Code § 297.1(21) (Johnson, 105). As the definition states, not all water underneath the surface can be counted as groundwater. Aquifers and subsurface lakes are considered as groundwater; however, undersurface streams and rivers are considered as surface water. The state of Texas regulates surface water and groundwater differently. Therefore, before proceeding in the use of groundwater, a landowner should make sure that the water in question is classified as groundwater.

Aquifers are the main source of groundwater in Texas. Not all the water flowing under the earth's surface is potable by humans or can be used for irrigation; some contains mineral salts, which can cause the water to have a bad taste or is sometimes toxic for vegetation. The Texas Water Development Board states that groundwater provides almost 60% of the state's water supply. Over 60% of this amount is used for irrigation and agricultural purposes. Aquifers contain the most amount of state's water.

The total of nine main aquifers and twenty-three minor aquifers provide fifty-nine percent of all the water supply in Texas (Porter 2014). Moreover, aquifers support the majority of rivers in Texas, and some of them are home to many endangered species.

Absolute Ownership

Regulation and allocation of groundwater have been at the center of Texas water policies for a long time. The rule of capture for groundwater has its origin in Greek and Roman law. In ancient Greece, the property law benefited free people (Drummond, Sherman & McCarthy, 2004). Many Greek scholars wrote about property law, and some of them wrote specifically about water rights. Homer, the ancient Greek poet, whose birth is believed to be around 750 BC (www.poets.org), is known as one of the first intellectuals to have discussed groundwater law, as it is later known in America. In book twenty-one of *The Iliad*, Homer described oceans as the font of all water resources in the world (Atsma, nd). This concept, known as the Oceanus Theory recognizes that all the flowing water in springs, rivers, streams and aquifers derives from the oceans and returns to the oceans as well (Mace, Ridgeway & Sharp, 2004).

Thales (640 BC), who is recognized by Aristotle (384-322 B.C.) as the father of Greek philosophy, was a firm believer of the Oceanus Theory, describing water as the origin and end form of everything. In his book *Meterologicia*, Aristotle expanded the Oceanus theory by developing a new hydrologic theory, known as the Condensation Theory. This theory considers the air as the first element that generates the groundwater, and implies a direct connection between groundwater and surface water in a unique hydrological cycle by stating:

> [T]he air surrounding the earth is turned into water by the cold of the heavens and falls as rain . . . [and] . . . the air which penetrates and passes the crust of the earth also becomes transformed into water owing to the cold which it encounters there. The water coming from the earth unites with rain water to produce rivers. The rainfall alone is quite insufficient to supply the rivers of the world with water. (Mace et al, 2004, 66)

In 451 B.C., the Romans created the first written law, called Twelve Tables, which was very influential in the further development of property law. Drummond et al (2004) state that the Roman Twelve Tables are probably the first Western legal document to contain written water regulation and to provide a remedy when a landowner's use of rain water causes damage to a neighbor's land. Moreover, the Twelve Tables provided four servitudes, defined as "rights vested in a person as owner of one piece of land over another piece, effective not only against its owner, but against all" (Cited by Drummond et al, 2004, 19).

Later in 438 A.D., with the adoption of Theodosian Code by the Roman Empire then based in Constantinople, further information regarding water rights, water use and punishment for illegal deviation of water was provided. Book XV of this code stated that "Ancient water rights that are established by long ownership shall remain the property of the several citizens and not be disturbed by any innovation. Thus each man shall obtain the amount that he has received by ancient right and by custom lasting to the present day" (Cited by Drummond et al, 2004, 20). This is probably one of the first definitions of water rights under the concept of private ownership. However, this definition carries an

ambiguity since it does not discuss all types of water rights rather than the ancient rights to the water.

An overall review of these statements clearly indicates that Roman society considered water as a vested property right of citizens rather than only a right to use or capture the resource. The absence of liability implied in the absolute ownership rule can clearly be seen in the writings of jurists in ancient times. One of the most distinguished jurists was Ulpian, who claimed, in his Ad Edictum, that "anyone who fails to protect himself in advance against anticipated injury [by work carried out on neighboring land] has only himself to blame" (Cited by Drummond et al, 2004). Some scholars consider this passage pivotal in the British court's 1843 decision in Acton v. Blundell, and the contemporary reaffirmation of the rule of capture in Texas.

Marcus Claudius Marcellus (45-23 BC) is a well-known jurist, who contributed in consolidating the basic concepts of the current groundwater law. The following passage based on Ulpian's and Marcellus' writings, which later became a part of Digest, is cited by Drummond et al (2004), as fundamental in shaping the current groundwater law known as the rule of capture: "Next, Marcellus writes that no action, not even the action for fraud, can be brought against a person who, while digging on his own land, diverts his neighbor's water supply" (22).

Rule of capture

History has always played an essential role in Texas water law development. Roman law, and to a smaller extent Greek law, influenced European jurisprudence throughout history, including the Spanish and English legal and cultural systems, both of which were influential in the formation of the current law in Texas. As a former colony

of Spain, Texas law is automatically influenced by Spanish jurisprudence. Texas law is also influenced by British law, although Texas was never a British colony. The Republic of Texas adopted the English common law in 1840. This made English vision and management strategies very crucial in shaping the current legal perspective on groundwater regulation in Texas. Originally, the Spanish water rights, influenced by Justinian law, exempted the landowner from liability for water damages. The only limitation to the landowner was that the use of water couldn't be with malicious intentions or just to deny access of water to a neighbor. Some scholars believe that it is the first recent restriction to the rule of capture in Texas. During the Spanish domination in Texas, surface and groundwater was differently regulated for a thousand years. Surface water was under the sovereign power, however, the groundwater was considered the property of a landowner.

The Texan rule of capture is a "judge-made" law derived from the English common law (Texas Water Law, 2015). It is believed that this rule was first articulated in 1843 in Acton v. Blundell, when a coalmine owner pumping water caused the depletion of neighboring wells, and the court recognized no liability to the owner of the mine. The state of Texas officially adopted the rule of capture in 1904 in its decision in Houston and T.C. Railway Company vs. East. In this case, the railroad company captured 25,000 gallons of water daily, leading the well of a neighboring landowner to completely dry up. The landowner sued the company, but the court voted in favor of the company. In support of its decision, the court relied on previous courts' decisions, such as Chasemore v. Richards 1859 in England in which the court ruled in favor of the manufacturers' pumping groundwater with the intention of selling it to a city or to use for industrial

purposes rather than for domestic purposes. As Potter (2004) states in "History and Revolution of the Rule of capture" the court's decision in Houston and T.C. Railway Company vs. East was based on two public policy considerations:

(1) Because the existence, origin, movement and course of such waters, and the causes which govern and direct their movements, are so secret, occult and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would therefore be practically impossible, and

(2) Because any such recognition of correlative rights would interfere, to the material detriment of the commonwealth, with drainage of agriculture, mining, the construction of highways and railroads, with sanitary regulations, building, and the general progress of improvement in works of embellishment and utility.

After a severe drought in 1910 and another in 1917, the Texas Supreme court applied the first modification in the rule of capture and passed the Conservation Amendment (article 16, §59). The new regulation stated that the conservation of the state's natural resources, including water, was a public right and duty and also vested the Legislature with the power to pass any necessary law to regulate natural resources including groundwater. The conservation amendment also allowed the establishment of conservation districts to improve the management of groundwater resources. In addition, these districts were given the regulatory authority and the political power of the government to manage the groundwater, provided they would retain the rule of capture as the base. High Plains Groundwater Conservation District No. 1 was the first conservation district, founded in the Texas Panhandle in 1951 (Texas Water Development Board).

The Texas Supreme Court has continued to uphold the rule of capture. Some important cases upholding the rule of capture are: Texas Co. vs. Burkett (1927), City of Corpus Christi v. City of Pleasanton (1955), Beckendorff v. Harris-Galveston Coastal Subsidence Dist. (1977), Friendswood Development Co. v. Smith Southwest Industries (1978), Denis v. Kickapoo Land Co. (1989), Barshop v. Medina County Underground Water Conservation Dist. (1996).

In 1999, the Texas Supreme Court reaffirmed once again the rule of capture in Sipriano v. Great Spring Waters of America, Inc., when Henderson County landowners sued the Ozarka Spring Water Co. because their wells were severely depleted by Ozarka's pumping about 90,000 gallons of water each day from neighboring land. In this case the landowners asked the court to abolish the rule of capture and adopt the rule of reasonable use, like almost all other states in the US, but the Supreme Court refused to modify or replace the rule of capture with an alternative common law. The reason for this was that the Supreme Court emphasized that groundwater resource management fell under the Legislature's responsibility. As noted in The History of the Rule of capture Doctrine in Texas by Darling (2016) the Court comment as follows:

> By constitutional amendment, Texas voters made groundwater regulation a duty of the Legislature. […] It would be improper for courts to intercede at this time by changing the common law framework within which the Legislature has attempted to craft regulations to meet this State's groundwater conservation needs. […]

Even though, the rule of capture has been revealed as harsh, the Texas Supreme Court is unwilling to shift to an alternative solution such as the rule of reasonable use or

the restatement of torts. However, the court has consistently reinforced the Legislature's power to modify the existing rule of capture for groundwater. Since the case involving Ozarka, the Legislature has made significant progress in groundwater management across Texas. the number of Groundwater Conservation Districts has risen to 100 covering over 80% of annual groundwater usage in the state, and the Legislature has approved a plan for Groundwater Management Areas (GMA) where groundwater districts with authority over the same aquifers can work together to determine the Desired Future Conditions (DFC) for these aquifers (Chapter 36 of the Water Code). However, history shows that Texas' approach to groundwater management is increasingly incompatible with the geographic and population growth patterns in many parts of the state.

Exemptions to the rule of capture

1. **Malice**-Under this limitation a landowner cannot pump underground water maliciously with the purpose of damaging a neighbor's activity;
2. **Waste**-This restriction prevents any wasteful use of groundwater.

Historical analysis of cases shows that intentional malicious damage to a neighbor and wasteful use of groundwater can be difficult to prove in court. Indeed, for finding out that a landowner has taken water with malicious intentions to injure a neighbor, the plaintiff should prove that "no other possible explanation for why the defendant was draining the complainant's property other than malicious spite exists" (Drummond et al., 2004, 46). Although the waste limitation has been very controversial on many occasions, the court's decision has been revealed as inattentive to this principle. The court's conclusion in City of Corpus Christi v. City of Pleasanton in 1955 is a famous example of the latter situation. In the framework of this case, the city of Corpus Christi stipulated a

contract with the Lower Nueces River Supply District, 118 miles away, to receive about ten million gallons of groundwater per day. According to evidence, almost sixty to seventy percent of water never reached the destination due to losses caused by transpiration, evaporation, and seepage (Drummond et al., 2004, 47). In conclusion, the court recognized that the landowner's use of water was lawful under the common law interpretation, even if a huge amount of water would have been lost during the transportation. The court emphasized that making modifications to this rule could not have been a court's duty because through the conservation amendment, the court assigned such decisions to the Legislature.

3. **Subsidence**- This limitation is the most recent exception to the rule of capture. Over-pumping of groundwater over the years 1940-1960 in Harris and Galveston Counties had been discovered to be causing subsidence (Johnson, 2001). When there was enough evidence to link the growing water extraction and subsidence, local authorities recognized the need to consider limitations for groundwater usage. The region requested the Legislature for the establishment of a conservation district in the area that led to the creation of Harris-Galveston Subsidence district. Since then subsidence has been considered as another exemption to the rule of capture for groundwater use in Texas.

Ambiguities in the rule of capture

Surface Water and Groundwater: Hydrological Connection, Political Disconnect

The severe droughts in the nineteen fifties made many scientists and policy-makers start reconsidering the validity of the rule of capture for groundwater allocation in Texas. Opponents recognized this rule as inappropriate to regulate the state groundwater

resources primarily for one basic reason: the nature of water as fluid. As noted by Thales, and supported by contemporary science, all water in nature, either flowing on surface or underground is part of an interconnected hydrologic cycle. Each drop of water which one day flows on surface, can be flowing beneath the surface another day. Professor Glennon in his book *Water Follies* (2002) states that groundwater and surface water merely determine the temporary physical location of water which can constantly change from surface to underground and vice versa. Streams and rivers recharge aquifers and aquifers supports the flow in rivers and streams.

Despite the fact that groundwater and the surface water are interconnected in a unique hydrologic cycle, the state of Texas regulates them as separate. The surface water is highly regulated and counts as the state's property; however, the groundwater is poorly regulated and is managed under private property rights of absolute ownership.
The combination of severe droughts with population and economic growth has put a lot of stress on surface water supplies which made the groundwater economically more convenient option and vulnerable to unreasonable use. It seems that the groundwater regulation in Texas fails to scientifically consider the hydrologic connectivity among surface water and groundwater that obviously need to be managed through a conjunctive strategy.

Property rights

A frequently discussed issue related to groundwater property rights in Texas is whether the rule of capture implies the absolute ownership of groundwater. The doctrine of absolute ownership provides that the owner of the land also owns the water underneath that land. A historical review of numerous court decisions confirms this interpretation of

groundwater law in Texas, which suggests that a landowner owns the groundwater in place. However, looking from a different angle, the rule of capture allows a landowner with the bigger pump to drain the neighboring wells. The second issue raised in the context of absolute ownership is quantifying the property right. Considering the nature of groundwater, quantifying the water rights for a particular section of property cannot be accurate. Measuring the amount of water that exists beneath a property is almost impossible due to the fact that water does not remain in one place. It flows from underneath a property to another neighboring property. Several other factors can influence the amount of water that flows under a particular portion of land. According to Ellis (2004) some of these factors are the type of aquifer, recharge and discharge possibilities, the amount of rainfall and the production habits of neighbors. The difficulty in quantifying the groundwater underneath a particular area could suggest that is reasonable to define the absolute ownership right at the moment of capture rather than when the water is still underground. "It is much easier to define the moment of capture as the moment the property right vests, which leaves the landowner with nothing more than a mere expectation of production for water still in the ground" (Ellis 2004 , 92).

The rule of capture and Groundwater Conservation Districts: the two overlapping regulations

Although over one hundred years of groundwater resource management revealing the rule of capture to be destructive rather than beneficial, the Supreme Court of Texas and the Legislature have yet to undertake any effective action to address groundwater management related issues.

The Texas Supreme Court, reasoning that modification and the replacement of the rule of capture could not be a Court duty, assigned the full responsibility of modifying or replacing the rule of capture to the Legislature. Recognizing that the rule of capture's inefficiency in allocating groundwater rights, the Texas Legislature has created GCDs as supervisory local authorities. Rather than a solution, this action has generated even more serious challenges, because now the groundwater in Texas is governed by two almost opposing rules: the rule of capture and GCDs (Schafersman, 2011). While outside of districts the absolute ownership is the only rule for groundwater management, under GCDs authority, alternative rules such as the correlative rights doctrine partially govern. This means that under the districts authority, there could be restrictions to the rule of capture since the districts can control the groundwater withdrawal other than for domestic and livestock wells. Moreover, in some cases the districts can manage the groundwater export and off-site transfers. In these conditions, the GCDs' greatest benefit is only the mitigation of harms to individuals and environment, leaving in place the fundamental tensions between individual property rights and water as a shared resource. Schafersman (2011) believes that ending the groundwater issues in Texas and abolishment of rule of capture necessitates an action by federal court since for political reasons, Texas courts and Legislature are unwilling to solve the issue on their own.

Unregulated Areas: "White Zones"

Although Texas has almost one hundred groundwater conservation districts, many areas are still uncovered by any district. In these unregulated areas, known also as "white zones," the groundwater is regulated only by the original rule of capture adopted more than a century ago. After many disputes over groundwater rights in unregulated lands,

many people expected that either the Supreme Court of Texas would have modified the rule of capture or the Legislature would have taken action to create more conservation districts in order to cover all state lands. Many believes that the rule of capture encourages the wasteful use of groundwater even this is against the rule of capture provision for anti-waste of groundwater. Moreover, considering that GCDs are the state's preferred method for managing groundwater, the existence of white zones seems controversial. There is a lack of consistency and coherence between the Court and legislative actions. It seems like a vicious circle where the Court does not intervene to modify the rule of capture passing the responsibility on the Legislature, that lets the disputes reach the court when it does not take any action to regulate the white zones.

When Land Development Rules Contradict the Texas Water Code

According to the Office of the State Demographer and the Texas State Data Center's 2014 predictions, the Texas population is projected to grow up to 54.4 million in 2050 (Potter and Hoque, 2014). Southcentral Texas is one of the fast growing areas in Texas and is shifting from rural to urban at an incredible pace. This presents many challenges for water allocation plans especially under drought conditions and increasing development. The contractual frameworks provide the land developers with the right to use restrictive covenants when they develop the land for residential use. "Restrictive covenants are private covenants undertaken by landowners irrespective of any GCD regulation" (Potter and Hoque, 2014). A subdivision has the power to ban property owners from drilling a domestic well, while the Texas Water Code does not allow a GCD to restrict the domestic use of groundwater.

The power of land developers overpasses the Texas Water Code also in oil and mining practices. While the Texas law does not require a permit for water wells engaged in exploration practices for oil and gas and for mining activities, a developer can decide to use the restrictive covenant to prohibit any of these operations.

The Controversial Funding Methods of Groundwater Conservation Districts

Essentially, a GCD can accumulate the necessary funds for the operation of the GCD via two main policies: property taxes and well permitting and production fees (Lesikar, Kaiser & Silvy, 2002). Some groundwater conservation districts have been created based on a public vote. The same procedure is needed for confirming funding methods and mechanisms. In effect, many times local citizens are not willing to pay more taxes on their properties. Thus, well permitting and well production fees become central for a GCD to raise funds. Funding GCDs mainly through well pumping and well permitting appears contradictory considering the fact that the primary reason for groundwater conservation districts' creation is the protection of groundwater resources and aquifers. One can ask, is not this policy an encouragement to issue more permits for new wells, especially when a GCD does not have enough money to run efficiently or risk bankruptcy?

II. ALTERNATIVE REGULATIONS OF GROUNDWATER MANAGEMENT

Reasonable use

As the population of the United States significantly expanded over the past century, the need for water for agricultural and industrial purposes increased. Scientific discoveries and technological advancement changed the general consideration of water as infinite resource. As a result, many states, mostly Eastern states, abandoned the groundwater rule of capture for the reasonable use doctrine (Johnson C.W., 2004). This doctrine "limits a landowner's use to beneficial uses having a reasonable relationship to the use over his overlying land" (Water Systems Council, 2003). The reasonable use strategy "provides a juridical remedy to landowners if the unreasonable use of groundwater by others harms their own reasonable use" (Holladay, 2006). Under the reasonable use of groundwater, a landowner can pump any amount of water he or she wants from the aquifer underlying his or her land, in the absence of any wasteful uses. "Any use on any land other than the tract where the well is situated is categorically classified as unreasonable use, no matter how beneficial it may be" (Johnson C.W., 2004, 12). The reasonable use doctrine does not consider any proportional sharing of water and any preferences for prior consumers.

Holladay (2006) argues that supporters of the reasonable use strategy point out that the limitations implied in this doctrine would effectively protect groundwater resources from being excessively pumped. It helps states to better manage groundwater, especially in view of greater future demand because of population growth in urban areas.

Albright (2006) states that many opponents don't see great differences between the application of reasonable use and the rule of capture, beyond the on-location restriction. They also claim that the rule of reasonable use violates their private ownership rights and does not consider any protection for prior users. Some other landowners see the reasonable use as violating their right to market their water.

Additionally, some opponents believe that the reasonable rule is ineffective if neighboring states do not adopt the reasonable use doctrine as well. They claim that even if the reasonable use limits the excessive use and exportation of groundwater, it remains useless if the neighboring states do not comply with the same rule (Durant and Holmes, 1985).

Prior Appropriation

Many Western states use the prior appropriation rule for managing groundwater resources. Prior appropriation is very similar to the surface water regulation in Texas, which is based on a permit system. This management strategy allocates water rights to the first user who puts a specific amount of water to beneficial use (Tarlok 1979). Prior appropriation was originally adopted as a strategy in a time of water scarcity. Additionally, it was thought as a way to protect the first settlers' right to water resources, and consequently the rule of beneficial use was enacted to protect later landowners' rights against wasteful use by prior settlers (Gopalakrishnan 1973). The permit-based strategy provides a better legal protection for senior users. Users who started using water resources before the permitting system are typically granted grandfathered rights (Albright 2006). Complete application of the prior appropriation rule is quite impossible

because every use of water by junior rights holders will affect seniors' access to water resources (Holladay 2006).

Supporters of the prior appropriation doctrine see this strategy as effective to protect water rights especially in times of water shortage and drought. This management strategy promises water stability and encourages landowners to invest substantially in their land and water pumping equipment.

Opponents of prior appropriation claim that this strategy would not be efficient in addressing groundwater resource issues in Texas. The main reason behind their opposition is the arid climate and long drought occurrences in Texas (Texas Water Law, 2015). The Holladay (2006) states that the opponents of this management strategy believe that methods which emphasize sharing of water would better address the state's water problems than the prior appropriation strategy. Additionally, the application of such a method in Texas would necessitate a large modification of the rule of capture in this state.

Correlative rights

The concept of correlative rights for water was first introduced in the twentieth century by the states of Minnesota and New Jersey in order to prevent intensive pumping of groundwater for selling outside of recharge areas (Dellapenna 2013). In Katz v. Walkinshaw (1903), the California court interpreted correlative rights as overlying landowners who use the same aquifer. These landowners must gain pumping rights in proportion to their land area and aquifers' safe yield for irrigation use (Sax 2002). Some consider the court's decision in Katz v. Walkinshaw (1903) a variant version of reasonable use doctrine. To clarify the concept of correlative rights, Holladay (2006) states that in situations when all reasonable water necessities cannot be met, ratable

reductions should be taken into consideration. Applying correlative rights to water rights limits a property owner's right to only the amount that is needed on one's land, and the surplus would be available for appropriation by other landowners (Johnson, 2004). Using this additional water for off-site uses is possible only if the water is not needed for any on-site use. Off-site marketing of groundwater should be immediately stopped in times of drought or water scarcity. Both conditions form a significant obstacle for free marketing of groundwater that makes supporters of free groundwater marketing align against the adoption of correlative rights as a management strategy. Proponents of this doctrine consider this doctrine an efficient policy for times of shortages or conflicts of interest because each right holder would be eligible to a portion of the shared resource.

Johnson (2004) argues that one negative aspect of correlative rights doctrine is that it is difficult to determine the allocation that is "fair and just," and that determining what counts usually leads to litigation and a long legal process. In effect, the description of "fair and just" in common law doctrines has always been complex, and a subject of debate for scholars.

The Restatement of Torts rule

The doctrine of the restatement of torts was created with the aim to address the increasing demand for water resources. American judges and policy makers made efforts to collect the best aspects of American states' water laws. The restatement of torts embraces some notions of both correlative rights and the reasonable use doctrines; there is no preference for on-site uses, and the reasonableness of practices is determined by comparing the reasonableness of their usage (Johnson, 2004). Section 85 of restatement

of torts adopted by the American Law Institute states conditions under which a well owner is liable for groundwater pumping:

- causes well interference by lowering the water table or reducing water pressure;
- results in pumping more than the well owner's reasonable share; or
- interferes with levels of streams and lakes that depend on groundwater Holladay 2006)

The doctrine of restatement of torts, known also as the rule of beneficial use, is not based on the proportional sharing of resources as in correlative rights; however, it "can take into account uses that are more beneficial than others" (Holladay 2006). The reasonableness can differ as it is observed case by case. Some critics point out that although the restatement of torts protects aquifers from over-pumping practices, it does not encourage on-tract use of water to reassure the recharge of the aquifer.

III. DECENTRALIZED STRATEGY FOR GROUNDWATER MANAGEMENT

Groundwater Conservation Districts

More than a decade after the adoption of rule of capture for groundwater in Texas, drought and population growth had contributed serious concerns over the availability of this natural resource. In 1917, with enacting the Conservation Amendment, the Texas Constitution recognized groundwater preservation and conservation as public rights. In 1949, the Texas Legislature, exercising its authority conferred by the Conservation Amendment, created a petition for the construction of conservation districts and identification of groundwater management areas (GMAs) (Holladay 2006).

Since their foundation, conservation districts have managed most of the groundwater resources in Texas. Chapter 35 and 36 of the Texas Water Code state the legal authority and governance of Groundwater Conservation Districts, and their supervision by state agencies, specifically TCEQ and TWDB. Chapter 36 of the Texas Water Code (TWB) establishes the foundation of the Groundwater Conservation Districts and their function in term of powers and duties. Section 36.0015 explains that conservation districts are "to provide for the conservation, preservation, protection, recharging, and prevention of waste of groundwater, and of groundwater reservoirs or their subdivisions, and to control subsidence […]."

In Texas, Groundwater Conservation Districts (appendix I) are identified as political sub-divisions, and as such they are required to behave according to Texas laws for political subdivisions. Election of board members, ethical practices and open government are mandated. Not all groundwater resources are covered by a local

groundwater district. In these areas so called white zones, no conservation district operates; thus groundwater resources are not protected by any management authority. Without any district managing the groundwater in the area, property owners not only risk losing their groundwater to neighboring landowners with the same water rights, but also to water companies who plan to transfer huge amounts of groundwater at the state level (Porter 2013).

In 1997, the Legislature acted to enhance the groundwater management by passing Senate Bill (SB) 1. The new water planning law was not supposed to substitute for the existing rule of capture, but to provide more structure to groundwater usage rules under the private ownership concept. The act identified sixteen water planning regions with five-year cycle systems, on long-term regional planning, gathered into a State Water Plan (State and Regional Water Plans). By enacting SB1, Groundwater Conservation Districts were recognized as the state's preferred groundwater management method. In 2000, over 80% of the state's groundwater supply was provided by groundwater districts, leaving the remaining ten percent outside of any jurisdiction (Holladay 2006).

Stakeholders' reactions to SB1 were diverse. Some supported this act by claiming that the rule of capture is maintained, while groundwater can be managed at the local level; but opponents of the rule of capture, contest that the act to be ineffective because the groundwater rule of capture is outdated and obsolete. (Davidhizar, Robertson and Sullivan, 2014). Technological and scientific advancement have provided enough facts about the nature of groundwater, thus it cannot be considered a "secret occult," anymore (Mace, Ridgeway & Sharp 2004). In other words, current technology allows scientists to track groundwater and study more in depth its nature.

In 2001, Senate Bill 2 was enacted in order to partially address some of the legal gaps in Sipiriano v. Great Spring of America (1999). The Texas Supreme Court decided in favor of the water company, Great Springs of America, which was withdrawing 90.000 gallons of water per day for commercial purposes. In response to Sipiriano's argument regarding the abolishment of the rule of capture, the Court explained that such a decision fell under the Legislature's purview and not that of the Court. Moreover, the Court discussed that SB1 had recently allowed citizens to participate in groundwater resource management through districts, thus it was improper for the Court to modify the common-law regulation. The sixteen water planning regions created SB2 that aimed to create a water plan at the state level. SB2 included more regulations for groundwater conservation such as the introduction of "environmental flows," defined as the flow of water which is fundamental to maintain ecologically healthy rivers and streams that depend on groundwater resources (TWDB). Moreover, theSB1 and SB2 revised the GCD's authority on regulating groundwater, and the means and techniques by which the conservation districts could operate. However, these new provisions in some cases limited the GCDs' power in very important ways (Brazos Valley Water Alliance). According to the final conservation plan, by 2050 there could be a fifteen percent increase in water consumption patterns (Davidhizar et al, 2014).

It is not an easy task for Groundwater Conservation Districts to protect groundwater resources while respecting the Texas private property rules. The fact that districts can be sued by landowners for the violation of their private property rights limits the districts' ability in their decision making process. *EAA V. Bragg* (2013) demonstrates the difficulty of balancing private property rights and conservation goals, where, the trial

court ruled against the Edwards Aquifer Authority (EEA) that impeded landowners from pumping enough to irrigate their two commercial-level pecan orchards (Russell, 2014).

Despite these restrictions, GCDs, through their authority to limit well drilling, water pumping and exportation, many times succeed in making significant restrictions to the rule of capture. The Texas Water Code chapter 36.116 provides GCDs with the authority to regulate the spacing of wells " (A) requiring all water wells to be spaced a certain distance from property lines or adjoining wells; (B) requiring wells with a certain production capacity, pump size, or other characteristic related to the construction or operation of and production from a well to be spaced a certain distance from property lines or adjoining wells; or (C) imposing spacing requirements adopted by the board."

GCDs also have the authority to regulate the groundwater production by:

> "(A) setting production limits on wells;
>
> (B) limiting the amount of water produced based on acreage or tract size;
>
> (C) limiting the amount of water that may be produced from a defined number of acres assigned to an authorized well site;
>
> (D) limiting the maximum amount of water that may be produced on the basis of acre-feet per acre or gallons per minute per well site per acre;
>
> (E) managed depletion; or
>
> (F) any combination of the methods listed above." (Texas Water Code 36.116)

The Texas Water Code also provides rules that allows GCDs to require a permit for drilling a new well or expanding the size of an existing well in the area covered by a GCD requires a permit for drilling and operating. Before issuing a new permit, the district

must consider whether the water will be used for beneficial purposes in the framework of a district's management plan, and whether the new water pumping unreasonably affects groundwater resources or current permit holders. One of the most debated GCD rules regards limitation on withdrawals, where districts may consider heavy fines (sometimes up to 10,000) for violation against districts' management rules. Porter (2013) states that inside a district area, neighboring well owners can sue the well owner in violation; however, in white zones that are not covered by any management authority, such a lawsuit cannot be presented, as the rule of capture is the only rule prevailing in such areas.

In view of future droughts and demographic growth in Texas, Porter recommends that GCDs require meters on all wells. Porter cites a 2012 study by Stacey Steinbach, executive director of the Texas Alliance of Groundwater Districts, stating that sixty percent of groundwater districts require meters on at least some of their approved wells. Generally, landowners ask for the creation of a conservation district through a local petition process. Either the Legislature or the Texas Commission on Environmental Quality (TCEQ) can authorize the creation of groundwater districts. A newly founded district needs to develop a ten-year management plan to submit to the Texas Water Development Board. Each district is directed by a locally elected board that serves for four years. Members of the board decision about the allocation of groundwater is based on regional geologic characteristics and regional preferences (Holladay 2006). Population growth rate, access to different levels of technology and consumption patterns are some other factors that are crucial for policy-makers to take into consideration while defining regional regulations (Berry 1977). A few years after the creation of the first groundwater

district in 1952, Ackerman (1956) stated that three forces should guide the formulation of future water policy: geographical environment, demographical characteristics and technology. Districts funds are usually provided by user fees such as maintenance taxes, a tax on water exportation or through new well permits. However, some districts may consider applying local property taxes as well. Many GCDs struggle with finding enough funding sources because they have lower taxes and water usage fee rates. Some districts do not have enough groundwater production from large wells or enough numbers of new well applications (Porter 2013). Although local voters usually feel the need of a GCD in their area, they are unwilling to vote for additional taxes to fund projects.

Although almost all conservation districts work within the structure of chapter 36 of the Texas Water Code, many follow different regulations (Davidhizar et al, 2014). This strategy helps districts to effectively plan their responses to the specific needs of their regions. However, many Texans disagree with this policy recognizing it as unequal. Many companies and businesses believe that it is unfair that some commercial wells are monitored while others are not supervised. However, this monitoring process makes small farmers and ranchers feel better-protected about the future of their wells. They fear that without any regulations, they cannot compete with water companies who will deplete the water in their small wells. Environmental activists are also firm supporters of conservation districts as they consider this policy a guarantee for water stability in the state's aquifers. Another disagreement is when limitations for well-spacing conditions and maximum water withdrawal are applied differently, although the rule of capture is unique to every stakeholder. Some opponents claim that districts regulating the groundwater limits the land owners' property rights under the rule of capture. They

believe that, instead of establishing limitations for groundwater use, government should follow economic principles that will bring more social benefits (Albright 2006). Defenders of groundwater conservation management considers this strategy fundamental for the state's future water viability.

The percolating characteristic of groundwater makes the definition of groundwater boundaries difficult. Applying land limitation to define aquifer confines can sometimes create confusion in groundwater management. Policy makers felt it necessary to discuss district functionality when an aquifer lies underneath two or more management districts. Evidence showed that districts are careless in their policy making and do not pay enough attention to other communities that access the same aquifer (Johnson, 2001). As Drummond et al. (2004) state, sometimes districts use different data and scientific assumptions for choosing their strategies. This condition can cause management deficits especially when coupled with miscommunication among neighboring conservation districts.

Groundwater Management Areas

Groundwater Management Areas (GMAs) have been created to better organize the collaboration among Groundwater Conservation Districts, as part of a regional water planning program. Most of the time GMAs (appendix II) correspond with aquifer boundaries. As it is common that many groundwater conservation districts share the same aquifer, GMAs have the responsibility to determine the total impact of districts' use of groundwater resources in the region.

Section 35.004, chapter 35, of the Texas Water Code recognizes the Texas Water Development Board as the authority who shall designate GMAs undertaking a strategy

that covers all the state's aquifers. Currently, there are sixteen management areas in Texas. Each covers a different number of Groundwater Conservation Districts.

In 1997, the Legislature authorized the creation of Priority Groundwater Management Areas (PGMAs) to effectively manage the groundwater resources in areas with critical current or future (within next 25 years) groundwater issues such as groundwater contamination, freshwater shortage, and land subsidence. The Texas Water Development Board (TWDB), the Texas Commission on Environmental Quality (TCEQ) and the Texas Parks and Wildlife Department (TPWD) identified and designed PGMAs and where it was necessary, these entities decided for the creation of Groundwater Conservation Districts within those regions. In an area where the creation of a PMA is projected, citizens have two years to form a groundwater conservation districts or be annexed to an already existing district.

Desired Future Conditions

One important section of every regional management plan should be dedicated to defining Desired Future Conditions (DFC). Texas Administrative Code (Title 31, Part 10, §356.10 (6)) defines the desired future conditions as "the desired, quantified condition of groundwater resources (such as water levels, spring flows, or volumes) within a management area at one or more specified future times as defined by participating groundwater conservation districts within a groundwater management area as part of the joint planning process" (TWDB). Groundwater conservation districts collaborating within a management area must participate in defining the DFC through a joined planning process (Whiterspoon, 2010). DFCs differ depending on data available on aquifer conditions, geologic and geographic characteristics of areas (Mace, Petrossian, Bradley,

Mullican & Christian, 2008). DFCs must be achievable and compatible with goals set by management areas, these need to be approved by TWDB, who then estimates the available amount of groundwater that each district can consider for planning and permitting purposes.

Groundwater Marketing

Under the absolute ownership doctrine, landowners have the privilege of access to the groundwater under their property. Although this doctrine recognizes the water right as separately transferable, this strategy does not define any limitations for the amount of water that can be pumped. The state of Texas does not put any restrictions on inter-basin water transfer that makes the groundwater resources vulnerable and threatens the agricultural activities across the state. However, many western states recognize substantial subsidies for farmers that sometimes result in wasteful and economically inefficient groundwater uses. As Baxtresser (2010) states that "these policies hide the real cost of water-a cost that is climbing rapidly due to the climate change and population growth, both of which deplete freshwater supplies" (775).

The Pickens Plan to pump and sell the groundwater is a current example of water policy discussions around the marketing of groundwater in Texas. T. Boone Pickens, famous in the oil industry, has planned to pump water from the Ogallala aquifer underneath his land in Panhandle, Texas, and sell it to cities in need of water located far away. Pickens, the founder of Mesa Water, hopes to withdraw huge amounts of water from the aquifer and transfer it to regions desperately in need of water.

Over the past two decades, the emergence of Groundwater Conservation Districts by legislative act has provided more structure around the conservation of groundwater

resources. However, in the absence of state wide regulation, districts sometimes decide on very different management rules. While many of these districts consider modest restrictions on water pumping, others vote for severe limitations on water pumping or exportation (Griffin, Characklis, 2002). Groundwater marketing gets further complicated as many districts are founded within political boundaries of counties, rather than hydrologic boundaries of aquifer. In other words, the management policies do not reflect scientific-based strategies, but political and economic preferences of specific group of people.

Another recent conflict on water marketing took place in mid-western Hays County. A Houston-based private water supplier, Electro Purification (EP), had been planning to pump approximately 5.3 million gallons of water per day from the Cow Creek Formation of the Middle Trinity Aquifer. The company wanted to sell the water to the city of Buda, to the Goforth Special Utility District, and to developers in Mountain City's extraterritorial jurisdiction. Although this area was under the jurisdiction of Groundwater Management Area 9 (GMA 9), within the Edwards Aquifer Authority (EAA), EAA authority did not extend to the portion where the Trinity Aquifer flows beneath the Edwards Aquifer. It also fell outside the jurisdiction of Hays Trinity Groundwater Conservation District (HTGCD).

In the absence of a groundwater conservation authority to enforce groundwater extraction restrictions, and relying only on the rule of capture, EP could have pumped an unlimited amount of water from the Trinity Aquifer without any consideration of neighboring wells that risk running dry. Residents of Wimberley protested, fearing the EP plan would drastically decease the water level in their wells, used for domestic

purposes. On June 20, 2015, a legislative bill brought this unregulated area under the authority of Barton Springs/Edwards Aquifer Conservation District to manage and control water withdrawals from that part of the Trinity Aquifer underlying the Edwards Aquifer in southern, central and eastern Hays County. Groundwater conservation districts have not had the power to deprive investors of their marketable groundwater rights. District rules may apply some restrictions for well permitting, annual withdrawal or off-tract water transfer. However, outside of these conservation districts, the marketing of groundwater remains completely unregulated. The case of EP is addressed in more detail in Chapter IV.

Some proponents recommend water marketing as a potential solution to reallocation and conservation problems. They consider the market as an efficient regulator of supply and demand that would increase conservation and discourage waste (Glennon, 2004). However, Baxtresser (2010) sees this as a significant problem because of incompatibility of American groundwater common law with the reality of the modern market. He claims that many of these doctrines are out of date and never can solve water scarcity issues on a larger scale, nor support the idea that water should be understood as a finite resource.

In view of future droughts and climate change, the rule of capture is inadequate to protect state groundwater resources and the future economy of Texas. This rule not only discourages the efficient allocation of groundwater, this is discouraging also for investors in the water market because this doctrine does not protect their investments, as another user with a bigger pump can deplete their wells (Baxtresser, 2010). The policies for marketing of groundwater should be implemented by the Legislature at the state level,

before reaching the courts. Otherwise, state courts will continue to rely on the rule of capture, adopted over one hundred years ago.

IV. ELECTRO PURIFICATION CASE STUDY IN HAYS COUNTY, TEXAS

Introduction

The adoption of rule of capture by the Texas Supreme Court in 1904 was intended to resolve the legal and political conflicts over the groundwater ownership and management in Texas. However, the adoption of the rule reduced effectiveness in defending property rights in well-interference conflicts and preventing over-exploitation in aquifers. In response to groundwater problems, the Texas Legislature created Groundwater Conservation Districts (GCDs), beginning in 1951, charging them with the development of effective plans to address the issue.

GCDs have had a significant influence on monitoring groundwater use and management, but issues still persist regarding aquifer over-pumping and marketing of groundwater in Texas. As the literature review in the previous chapters illustrated, over 10% of Texas lands are not uncovered by GCDs and are regulated only by the rule of capture that provides small protection for groundwater resources in unregulated areas.

These unregulated areas or “white zones” become targeted by water supply companies who buy or lease these lands and start pumping huge amounts of water from the aquifers. The case of Electro Purification in Hays County is a good example of a company taking advantage of loopholes in Texas groundwater law in order to market the groundwater. This chapter will review the rule of capture in Texas through the lenses of EP plans in Hays County and discuss the community and legislative actions addressing the issue.

Electro Purification Plan in Hays County

Over the last five years, a Houston-based water company, Electro Purification (EP), has been making plans to pump groundwater from Hays County. EP's goal was to pump 5.3 million gallons of water per day by 2036 to sell to the city of Buda, the Goforth Special Utility District, and the Anthem Municipal Utility district that would provide water for further development near Mountain City. The land that EP leased from a private owner is located northeast of Wimberley in an area of the Hill Country where the groundwater is not regulated or protected by any authority. Therefore, their practice would be governed by the rule of capture only. The wells are drilled through the Edwards Aquifer all the way to the depth of the Trinity Aquifer. The water is intended to be captured from the middle portion of the Trinity Aquifer. Although the location of EP wells is within the Edwards Aquifer Authority (EAA) in Groundwater Management Area 9 (GMA 9), the EAA's authority does not extend to the portion where the Trinity Aquifer flows beneath the Edwards Aquifer. The site also falls outside the jurisdiction of Hays Trinity Groundwater Conservation District (HTGCD) to its west and Barton Springs Edwards Aquifer Conservation District (BSEACD) to its east. The following maps show the EP project location and the respective distances from nearby areas: Jacob's Well, Wimberley, Dripping Springs, Buda, San Marcos Springs and Kyle.

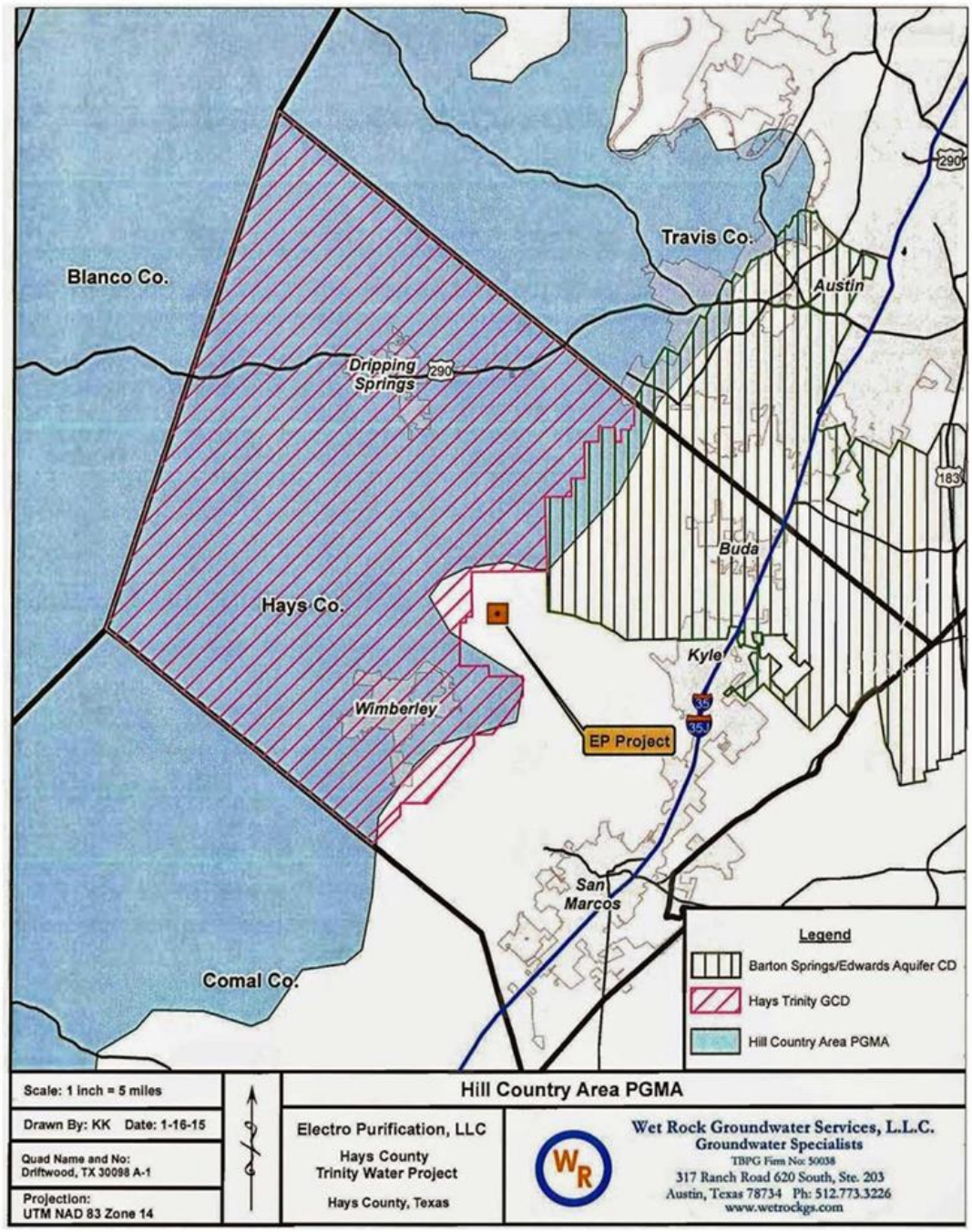


Figure 1. EP wells' location. Source: Rene Barker, USGS, retired hydrologist, groundwater modeler. Presentation at Texas State University in March 2015.

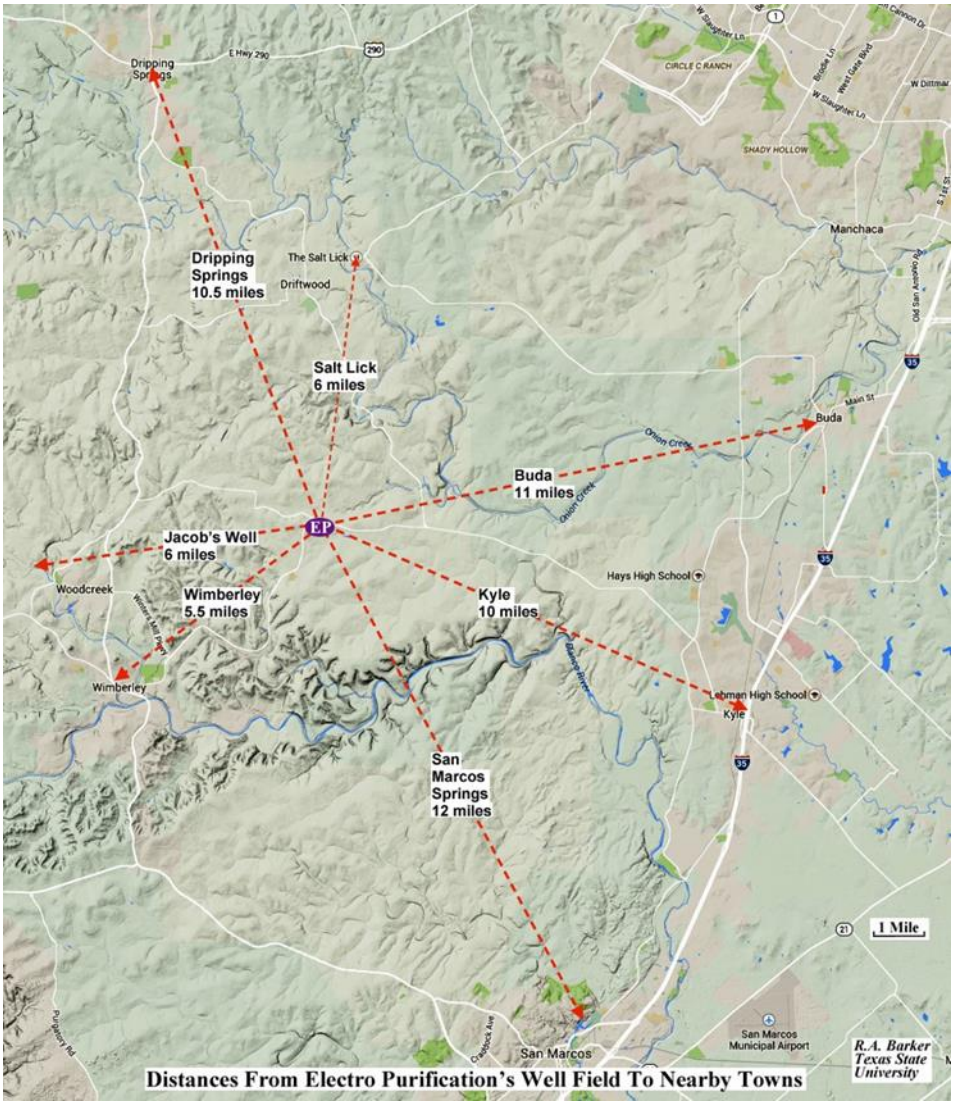


Figure 2. Distances from EP wells' field to nearby towns. Source: Rene Barker, USGIS, retired hydrologist, groundwater modeler. Presentation at Texas State University in March 2015.

In the absence of a groundwater conservation authority to enforce groundwater extraction restrictions, and relying only on the rule of capture, EP could pump an unlimited amount of water from the Trinity Aquifer. This caused serious concerns among the citizens in the neighboring areas, whose wells might be affected and might risk depletion.

In addition to the risk that the EP project may cause to nearby wells, EP's plan may be a threat to surface water resources in the area. According to Nico Hauwert, senior

hydrologist at the City of Austin Watershed Protection Department, during droughts the Trinity Aquifer discharges in Blanco River, which supports the flow in Barton Springs; "If the baseflow to the Blanco River near Wimberley were to cease, Barton Springs could dry up in three months" reported Hauwert (Watershed News, 2012).

Moreover, the Trinity Aquifer supports the baseflow in many springs and creeks such as Jacob's Well and Cypress Creek in Hays County, which consequently support the baseflow in other springs and rivers such as the San Marcos River (Baker, 2015).

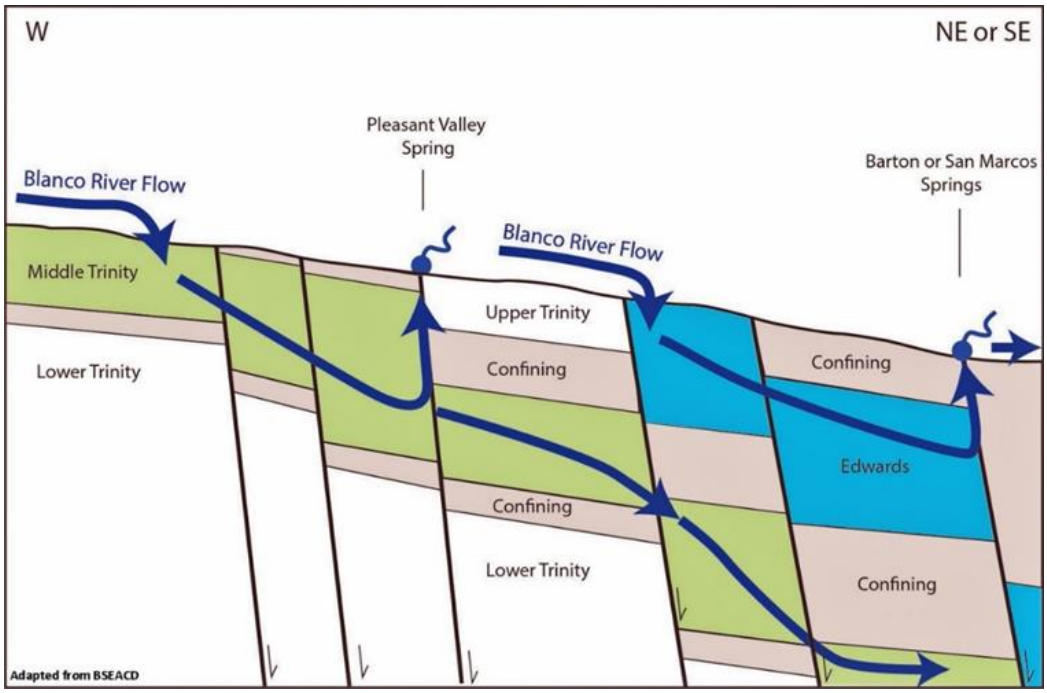


Figure 3. Blanco River flow in The Middle Trinity and Edwards Aquifers. Source: Rene Barker, USGIS, retired hydrologist, groundwater modeler.
Presentation at Texas State University in March 2015.

A similar case happened during the1990s, when the increasing demand for groundwater resulted in extensive pumping from the Trinity Aquifer, causing concern among citizens and policy makers about the regulation of groundwater. To address the present and future groundwater shortage in the area, the Trinity region was designated to

become a PGMA, giving county representatives some authority to manage and regulate the groundwater, and eventually to create a groundwater conservation district, which would further control the groundwater withdrawal from the Trinity Aquifer. After nine years, in 1999, a group of residents was formed to prepare a plan for the creation of a conservation district. One of the issues was whether to include a northern section of Bexar County. This portion was not originally part of the PGMA because it was under the authority of the Edwards Underground Water District (EUWD). At that time the EUWD was dissolved, and its authority was transferred to the Edwards Aquifer Authority, which did not have the power to manage water extractions from the Trinity Aquifer. Finally in 2001, a legislative act led to the formation of a GCD in northern Bexar County that could manage the Trinity Aquifer in that area.

Hydrogeology of the EP Wells' Area

Trinity Aquifer

The majority of water in the Hill Country comes from two primary underground sources: the Trinity Aquifer and the Trinity-Edward Plateau. The Trinity Aquifer has an area of about 41,000 square miles that extends from south-central Texas to southeastern Oklahoma. The aquifer passes through 61 counties in Texas, from the Red River in the North to the Hill Country in Central Texas, including the heavily-populated cities of Austin, San Antonio, Dallas and Fort Worth. The Trinity-Edward aquifer flows under a large portion of southwestern Texas, providing water for more than twenty counties from Gillespie to the trans-Pecos region located in west Texas (Echhardt, 2015). Water from these two aquifers is primarily used for agricultural purposes, but also for municipalities, businesses and multipurpose farms. The quality of water is extremely variable in the

Trinity Aquifer and is considerably lower than in the Edwards. In South-Central Texas the water quality is moderate with limited quantities of available fresh water.

Geology

The Trinity Aquifer is formed from a number of smaller aquifers that together create the Trinity Group consisting of several formations. The Trinity Group consists of two Cretaceous formations, Glen Rose on the surface and Travis Peak underneath the Glen Rose layer, which are classified as Upper and Lower. The Travis Peak has limestone, conglomerate, and calcareous silts. In vertical order, the Travis Peak is formed by different layers of Hensel, Cow Creek, Hammett, Sligo, and Hosston (LBJ-Guyton Associate, 2015, p.6). The area of interest to this case study is the lowest portion of the Edwards Aquifer and the Upper Glen Rose in the Middle Trinity, which are the areas most impacted by the EP project.

The figure on the next page, retrieved from the LBJ-Guyton report (2015), illustrates the local geologic units of the aquifers under the Trinity Group and the Edwards Aquifer.

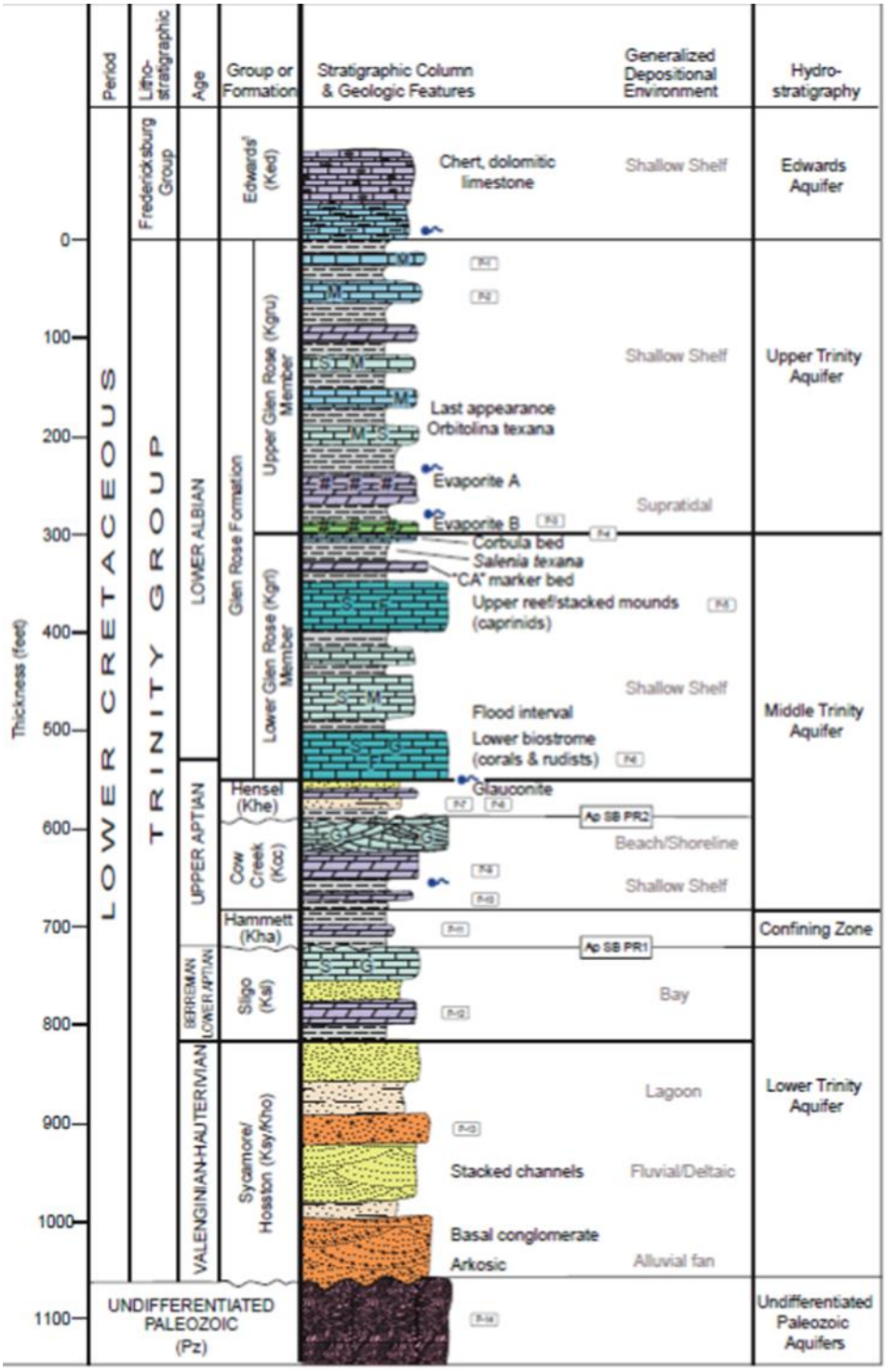


Figure 4. Stratigraphic column of the local geologic units and aquifers. Reprinted from Wierman, Broun and Hunt (2010) Source: LBJ-Guyton Associates, 2015, page 7.

Hydrology

The Trinity Aquifer is the major source of groundwater in areas nearby the location where EP has placed its wells, in the Hill Country to the west of the Balcones Fault Zone. This aquifer is subdivided into three productive intervals: Upper, Middle, and Lower Trinity units. EP aims to produce the proposed amount of water from the Middle Trinity, which contains the LGR, the Cow Creek and the Hensel (LBJ-Guyton Associates, 2015, p.10).

The Trinity Aquifer recharges very slowly, and it occurs primarily from rainfall, lakes and seepage; only a small amount of rain water (around 5%) actually recharges this aquifer (Eckhardt, 2015). Moreover, unlike the Edwards Aquifer, the water moves very slowly through the Trinity Aquifer, causing an extremely slow recharge rate in this zone. Recharge to the Middle-Trinity mostly occurs through precipitation, karst zones, and faults and fissures along stream waterways (LBJ-Guyton, 2015, p.12). According to LBJ-Guyton report (2015) the recharge via rainfall is more effective on the sandy surface of the Hensel formation; however, near to EP well's location, the Hensel is largely shaley facies, that prevents the effective recharge in this area.

Recharge to the Cow Creek Formation also happens via vertical leakage from the overlying sandy Hensel. However, Guyton Associates affirm that because of the hydrological and geological complexity in the area, additional data is needed to better identify the effect of recharge patterns on the wells in the area. Recharge to the Lower Trinity primarily occurs through leakage from adjacent zones, although the recharge is minimal in the Pedernales River basin located to the east of Blanco and north of Hays County. Based on some studies conducted by BSEACD, the Guyton report considers that

recharge to the Lower Glen Rose that occurs within the Blanco River watershed is more significant than the recharge that occurs within the Pedernales River basin, especially near the proposed well field.

Interflow between the Edwards and Trinity Aquifers

Aquifers are usually classified by the geologic characteristics of their units and most often they are managed independently (Wong, Kromann, Hunt, Smith & Banner 2014). This choice of management is because, in many cases, there is a minimal inter-flow between two or more conjunct aquifers. However, the aquifers' structure can change over periods of years by natural or human-made forces such as intensive pumping practices, and this can impact the flow path between aquifers.

The Edwards Aquifer is among the most used groundwater sources throughout the United States, providing water for various agricultural, industrial, domestic and recreational purposes to more than two million people in south central Texas. Over the last few decades, the fast-growing development across this region has increased the demand for water far beyond the ability of the Edwards Aquifer to meet the needs. Other concerns include the safety of endangered species whose lives depend on the Edwards Aquifer such as Texas Blind Salamander and San Marcos Gambusia.

The Trinity Aquifer that contributes to the recharge of the Edwards Aquifer is also over-stressed because of drought and the water drainage from sources in the area. However, data differs widely on the amount of this contribution. A survey study conducted by Eve Kuniansky and Kelly Holligan for USGS in 1994 shows that almost 360,000 acre feet of water annually flows from Trinity to Edwards. However, other research in 2000 by Mace considered that amount incorrect and lowered it to 59,000 acre

feet per year. In 2011, a study of the hydraulic relationship between the two aquifers stated that it is very difficult to estimate the flow between the Trinity and Edwards Aquifers, but the amount of water flowing from Trinity to Edwards is probably more than the 59,000 acre feet that Mace suggested (Green, 2011). A 2014 study by Wong et. al. shows that the groundwater flows laterally within the Edwards and Middle Trinity Aquifers. According to this study, under current geologic and hydrologic conditions, because of low permeability sections within upper and lower Glen Rose, the vertical flow is very restricted between the two aquifers. However, Wong and et. al. believe that the management strategies should not be based on current results because the over-pumping of the Middle Trinity Aquifer can cause vertical gradients that lead to a vertical flow between the Trinity and Edwards Aquifers (2014). This can cause a decrease in the water level of both the Edwards and Trinity Aquifers.

LBG-Guyton Report

In March 2015, the LBG-Guyton Associates conducted a specific study to evaluate the EP project in Hays County, Texas. They reviewed the existing data and conducted a preliminary evaluation of hydrological and geological features of the Trinity Aquifer. The goal of this study was to determine the possible impacts of EP's water production project on the nearby wells, within a radius of five miles from the location of EP's wells. According to The Barton Spring Edwards Aquifer Conservation District's estimation, there are about 1600 groundwater-supplied properties within two miles of the EP test-well properties.

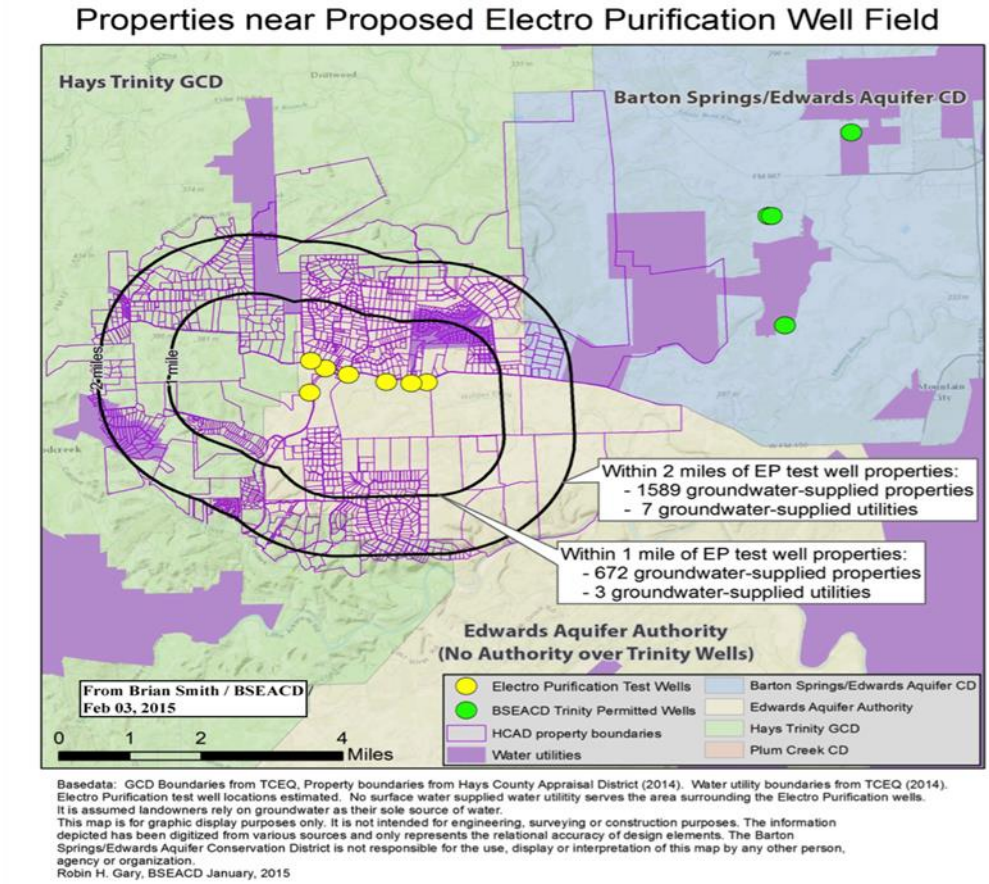


Figure 5. Properties near Proposed EP Well Field. Source: Rene Barker, USGIS, retired hydrologist, groundwater modeler.

Presentation at Texas State University in March 2015.

Based on the Texas Water Development Board Groundwater Database and Submitted Driller's Report database, the Guyton group identified 176 wells within a radius of 5 miles the location of the EP wells. 133 out of 176 wells were constructed in the Trinity Aquifer and of these 133, 117 were completed in the Middle Trinity Zone. The following table shows the number of wells completed in the Edward and Trinity Aquifers within a radius of 5 miles of EP wells.

Table 1. Identified Number of Wells Completed in Aquifers within Five Miles of EP Test Wells. Source: LBJ-Guyton Associates, 2015, page 10.

Aquifer			Wells
Edwards/Alluvium			43
Trinity	Upper	Upper Glen Rose	9
	Middle	Glen Rose, Undiff.	9
		Lower Glen Rose	54
		Hensel	14
		Hensel/Cow Creek	19
		Cow Creek	10
		Middle Trinity, Undiff.	11
	Lower	Sligo	7
Total			**176**

Findings and Recommendations

Guyton Associate experts conducted numerous simulations to estimate how much drawdown the EP well project may cause to the adjacent wells. For these simulations, they used the *Theis* Non-Equilibrium Equation (1935), which is a reliable model for quick calculation of the potential decline caused by pumping from a well. Just as in almost all scientific models, the *Theis* equation has some limits, thus the Guyton group limited its results to some specific scenarios, where the calculated decline in the distance of 0.5 miles from the EP well zone was less than 500 feet.

Table 2. Scenarios for Calculated Potential Drawdown. Source: LBJ-Guyton Associates, 2015, page 17.

Scenario	Pumping Rate (MGD)
1	1.5
2	1.5
3	3.0
4	3.0
5	5.3
6	5.3
7	5.3
8	5.3
9	5.3
10	5.3
11	5.3
12	5.3

Table 3. Summary of Calculated Drawdown (feet of water level decline). Source: LBJ-Guyton Associates, 2015, page 17.

	Distance from Well Field (miles)						
Scenario	0.5	1.5	2.5	3.5	4.5	5.5	6.5
1	170	150	130	110	100	90	80
2	280	250	230	210	200	190	180
3	350	300	260	220	200	170	160
4	Simulation Exceeds 500 feet of Drawdown						
5	Simulation Exceeds 500 feet of Drawdown						
6	Simulation Exceeds 500 feet of Drawdown						
7	Simulation Exceeds 500 feet of Drawdown						
8	Simulation Exceeds 500 feet of Drawdown						
9	490	400	330	270	220	190	160
10	Simulation Exceeds 500 feet of Drawdown						

As the table above shows, pumping an amount of 5.3 million gallons per day for a year may lead to a drawdown of 500 feet in neighboring wells. A different scenario

indicates that the groundwater pumping might not cause as much decline near the EP wells location. At this stage of study, only scenario 2 leads to a decline less than 500 feet near the EP wells' location in 30 years (Table 2). The variation in results, which is due to the different storage coefficient and transmissivity numbers in each scenario, confirms the need for more accurate data on the aquifer to be able to assess the possible decline in neighboring wells. However, there is a high level of uncertainty in the process of simulating the drawdown after 30 years of pumping, Guyton experts believe that the drawdown estimation can provide a great insight into the possible impacts of EP production

According to EP's calculation, the level of water in the testing wells is about 300 to 350 feet below the ground level, however, the Cow Creek top zone is almost 700 to 800 feet under the ground level. In these conditions, to maintain the level of water above the Cow Creek top, the maximum decline that could occur would be about 450 feet. The company wells would essentially become dry if water levels decrease over 500 feet.

The specific yield of the aquifer is another key factor that significantly influences the trend of water level decline. Almost all the scenarios simulated by Guyton Associates indicate that, once the production takes place, the water levels may decline immediately (to a lower level than the top of the aquifer) in wells near the EP wells field. After the groundwater levels fall below the top, the drawdown rate would slow down within 3 to 4 miles from the wells' location, but the water level would continue to decline near to the wells' field. Following are some of the main conclusions that the Guyton report documented:

1. Production of 1.5 MGD of groundwater for a year causes a drawdown of 160 feet near the EP wells' area, and almost 90 feet within 5 miles from the center of the EP project's location. The estimated drawdown by 3 MGD water extraction is over 350 feet near the EP wells' area, and almost 170 feet within 5 miles from the center of the EP project's location. Water withdrawal over 5 MGD for a year will cause a decline of over 500 feet near EP wells' location.

2. 30 years of groundwater pumping of 2 to 2.5 million gallons per day will cause the drop of water levels in Middle Trinity to the top of the Cow Creek.

3. It is important to consider that these evaluations of drawdown are related only to the Middle Zone of the Trinity Aquifer, using three of the seven wells for testing. If the Electro Purification Company continues its future production plans only in Cow Creek, then some decline would be noted in shallower wells.

4. If the total withdrawal from the Middle Zone of the Trinity Aquifer becomes high enough, the water levels could decline to the extent that some well owners, especially those with wells located near the EP's wells location, would need to lower the pump to produce the same amount of water for their domestic use.

Based on these conclusions, the Guyton report (2015), commissioned by Braun & Gresham (Attorneys At Law), proposes some recommendations in order to develop a better understanding of the geology and hydrology of the area. They recommend the implementation of a systematic monitoring program to properly establish the current water levels in the Middle Zone of the Trinity Aquifer for these reasons:

1. To understand the impact of the current demand on aquifer levels and endangered species and provide accurate analysis to predict the impact of any future water extraction by EP on the aquifer, nearby wells and the environment.

2. To observe the Trinity Aquifer patterns resulting from continuous pumping during drought conditions.

3. To develop a mitigation plan that includes a program for well owners whose wells are located near EP wells' location.

Community Movements, Electro Purification's View and the Legislative Act

Community Movements - TESPA

Trinity Edwards Springs Protection Association (TESPA), a Texas non-profit corporation, was instituted by a group of residents who believe that the EP project will negatively affect the nearby wells in the Wimberley area, causing serious problems in accessing freshwater, especially because people in this area totally rely on private wells located in the Trinity Aquifer. Moreover, "Many springs in the Texas Hill Country, such as Jacob's Well, are related to water movements through the Trinity and Edwards Aquifers" (David Baker, a member of TESPA and the executive director of Wimberley Valley Watershed Associations). Based on independent studies and news reports, WVWA feels suspicious of EP reports regarding the amount of groundwater available in the Trinity Aquifer, and EP's reported number of private wells in the area that depend on water from that portion of the aquifer (Cox, 2015).

TESPA created a petition to oppose EP plans in the portion of Trinity Aquifer beneath the Edwards Aquifer, and in March 2015, TESPA filed a lawsuit in Hays County District Court to stop any further development of the EP well project until the water

company would apply for a permit from the Hays Trinity Groundwater Conservation District. The lawsuit was titled as "Electro Purification and the landowners who leased the groundwater to Electro Purification as defendants," and it was filed on behalf of landowners who live within a half-mile of the EP wells' location.

TESPA's legal actions were based on two main approaches. First, despite many interconnections between the Edwards and the Trinity Aquifers, the Edwards Aquifer Authority failed to extend its authority over the Trinity Aquifer, where EP wells are located. Second, in Day vs. EAA (2012), the Texas Supreme Court decision was conflicting with the real application of the rule of capture in Texas (TESPA Press, Feb 25, 2015). The EAA and the State of Texas v. Burrell Day is an important milestone in the history of groundwater regulation in Texas, when the Texas Supreme Court recognized landowners' rights to groundwater even if they did not capture the water (EAA and the State of Texas v. Burrell Day, 2012). In other words, the decision clarified that property-owners have got an ownership interest in the water under their lands, which is valid even if they have not pumped the water before and their lands are located in the area of a conservation district that adopts "historical use" as its criteria for resealing groundwater permits (Alleman, Ruiz & Campbell Walker, 2012). This decision was a new interpretation of groundwater law. Even if the court continued to apply the rule of capture, it did not retain the historic "no liability" statement as interpreted in the Sipriano Case in 1999.

TESPA's long-term goal is to protect the springs in Central Texas, which are crucial for the well-being of streams and other water resources in this region. However, "The Electro Purification proposal has made us all aware of how vulnerable our

groundwater resources are. We all depend upon this water and we never imagined it could be taken away from us but it apparently can. We have made up our minds to fight back through the legal system," President of TESPA, Vichi Hujsak, says on their website (TESPA Press, Feb 25, 2015).

Electro Purification's View

Electro Purification started defending its project by providing some "factual background" about their company activities in a letter to Burt Cobb, County Judge in Hays County Courthouse, and a group of commissioners on January 19, 2015 (Wimberley Valley Watershed News: Response to Electro Purification Letter, (2015)). They claimed to be a small business, focused on providing water supplies for communities in immediate need and offering these communities the opportunity to build longer-term water solutions. Tim Throckmorton and Bart Fletcher, EP managers, explained that EP identifies customers with demands that allow a sustainable use of the aquifer. These projects go through an evaluation and qualification process under the supervision of professional geoscientists and hydro-geologists who are experts on groundwater in each area. Moreover, EP contracts include a "proven capacity" clause, and an exit mechanism in case the property becomes incapable of producing a sustainable amount of water to align with the project's goals. EP states that their contracts contain another crucial element, which is a "feasibility period." This concept allows them to acquire additional properties for integration in the project, if necessary, to meet their contractual commitments, while minimizing possible impacts to and from nearby wells.

In regard to their project in Wimberley, EP affirms that EP wells will be deeper than domestic wells, reaching the Middle Trinity Aquifer Cow Creek formation. And, as

most of the domestic wells are completed in the Upper Trinity Aquifer, the water extraction from EP wells would not interfere with domestic activities. EP managers argued that the Upper and Middle Trinity Aquifers are hydraulically disconnected, thus there is no way that pumping water from the Middle Trinity Aquifer affects the productivity of wells in the Upper Trinity. Tim Throckmorton and Bart Fletcher also ensured that for any impact on the existing wells in the Middle Trinity, EP will develop a mitigation plan to address the impact.

In response to the TESPA lawsuit, EP's manager, Tim Throckmorton, released a statement on March 20, 2015. Throckmorton wrote that TESPA intends to reverse the rule of capture and deprive Texans from their fundamental right to groundwater. His statement continues to say that none of the districts near to the area has any reliable scientific data related to the Middle Trinity Aquifer characteristics, in this area and EP, in coordination with the Barton Springs Edwards Aquifer Conservation District (BSEACD), the Hays Trinity Groundwater Conservation District (HTGCD), and Plum Creek Conservation District, will collect the first true dataset for this area, in order to be able to make informed decisions.

In March 2015, LBG-Guyton Associates released a report of their findings about the hydrologic and geologic features of the portion of the Middle Trinity Aquifer under the Edwards. As noted above, their report predicted up to 500 feet of drawdown in the residential wells if the EP project continues with its project in the area. In response to this report, Kaveh Khorzad, EP's hydrologist and the president of Wet Rock Groundwater Services, submitted a conflicting report to the Hays County Commissioners Court, regarding the impact of pumping 5.3 million gallons per day from the Middle Trinity

Aquifer. His report includes the claim that this portion of the Trinity Aquifer contains more water than previously assumed. However, Khorzad insisted that EP would not produce the full amount of water until 2036. Moreover, Khorzad disputed the use of the *Thie*s equation for assessing the water availability in the Trinity Aquifer, mentioning two reasons. First, this equation considers the Trinity Aquifer as uniform in character. Second, the model assumes no recharge through rainfall.

In the end, Judge Bert Cobb and Commissioner Will Conley were not convinced of EP's explanation of the issue and its opposition to the LBG-Guyton report. Conley affirmed that based on scientific improvements and alternations in aquifer features, the data may change. However, he recommended taking precautions and not going through "high risks for benefits of cheap water supply" (Hilsenbeck, 2015).

Legislation

HB 3405. On May 9, 2015, the Texas legislature passed House Bill 3405 with immediate effect. This bill was filed by Jason Isaac, the representative of Texas' House District 45, which includes the areas of Hays County where EP wanted to drill. HB 3405 extended the authority of BSEACD to the unregulated area, where EP has placed its wells. According to the new law, EP is required to obtain a permit from BSEACD for pumping water from the Trinity Aquifer and selling it to potential customers. Prior to this bill, several bills were filed by Isaac and Texas Senator Donna Campbell but previous bills failed.

HB 3405 has been the result of an active collaboration between local activist organizations such as Save Our Wells and Trinity Edwards Springs Protection Association (TESPA). TESPA filed a lawsuit in the Hays County District Courts that

opposed EP plans, on behalf of landowners living within half mile of the EP well site (Arguello, 2015). However, TESPA decided to drop its lawsuit when the 84th Texas Legislature passed HB 3405, bringing EP's well area under the protection of BSEACD.

Under the HB 3405 structure, groundwater permits will be issued in two different phases: temporary and regular permits (TESPA Facebook, 2015). BSEACD is responsible for providing the applicant with a temporary permit within a month from the application's date, for the amount of groundwater requested in the application. Regarding those applicants whose wells were operational before the new law went into effect, BSEACD must issue a temporary permit that allows them to pump groundwater at the maximum capacity of their wells (Collier, 2015).

In the second phase, BSEACD must provide the applicant with a regular permit for the same amount of water as the temporary permit. BSEACD can refuse the issuance of the regular permit if the water extraction will interfere with the achievement of Desired Future Conditions for the Trinity Aquifer, or if there will be "unreasonable impact" on existing wells (TESPA Facebook, 2015). Depending on how the conservation district will define unreasonable impact, EP will be allowed to have an indefinite right to pump groundwater from the Trinity Aquifer. The company firmly believes that its project will not have any impact on nearby wells, however, the residents hope that science can prove the current conditions of the aquifer and the impact of the EP project on their wells through various well tests.

In addition, HB 3407 was presented specifying that Goforth Special Utility District, the main potential buyer of EP production, "cannot exercise its power of eminent domain to condemn property outside of its service area for a project it doesn't own and

operate" (Satija, 2015). However, this bill did not reach the floor and failed in the pre-final stage. If this bill had passed, Goforth would not have been able to provide a pipeline for EP to transport the amount of water that was initially proposed. However, other ways were available to provide the pipeline for the EP project, as Leonard Dougal, Goforth's attorney, affirmed in an article in the Texas Tribune (2015). If the special district had lost its "eminent domain power," Buda might have used its authority to build the pipeline.

Implementation of HB3405

The passage of HB 3405 brought 1,300 acres of land leased by Electro Purification under the authority of BSEACD (Collier, 2015). The following map from Texastribune.com shows the new area in orange that was added to the BSEACD jurisdiction.

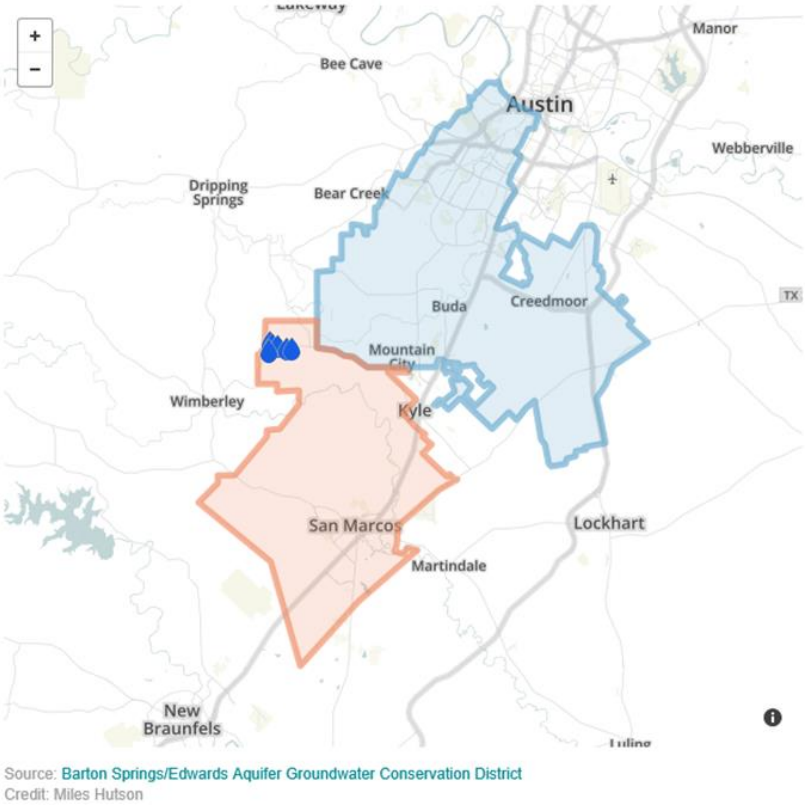


Figure 6. Implementation of HB3405. Source: BSEACD

HB 3405 provided a deadline for temporary permit application to sign in. BSEACD does not require all well owners to obtain a permit; wells with domestic and livestock purposes should be registered but do not need a permit. Owners of other wells located in the Trinity Aquifer, which produce water for large-scale use, need to apply for a permit, which will be issued in two phases: temporary and definitive.

According to Robin Gary, information coordinator of the BSEACD, under the new law, Electro Purification can still continue to pump water from the Trinity Aquifer at its maximum capacity with a temporary permit from the conservation district (Arguello, 2015). The temporary permits were finalized on October 22, 2015, where the EP's application for pumping 100 acre-feet or 32,590,000 gallons per year has been approved (Rollins, 2015). Temporary permits will allow existing wells to operate while the applications for regular permits are under evaluation.

There are still some critical issues regarding the future of the EP project in Hays County. More than six months may be needed to effectively define the concept of "unreasonable use" regarding the EP project. According to John Dupnik, the conservation district's general manager, the decision process could take over two years, potentially providing enough time for EP to produce the water it contracted (Collier, 2015). However, going forward with the initial plan might be financially risky for EP because the company needs to build a 15-mile pipeline to deliver the water, and if the final permit limits exponentially the amount of water that EP can pump, the project will be a failure and too costly for the company. Moreover, EP's contract to sell 1 million gallons of water daily to the city of Buda expired on October 20th because of EP's inability to prove the quantity and quality of its contracted water delivery (Buda, TX - Official Website).

Conclusion

The 84th session of the Texas Legislature demonstrated significant progress towards the sustainable management of groundwater. The dispute caused by EP's ambitious plan of pumping and selling over 5 million gallons per day confirmed an immediate need to extend GCD authority to cover unregulated areas. The nature of property rights still remains ambiguous under the rule of capture, which fails in protecting basic human and environmental rights to groundwater. This issue becomes a greater concern in times of drought and climate change, combined with the long process of groundwater recharge in Texas.

According to the LBJ Guyton Associates document, EP's long-term pumping of proposed quantities of water could seriously affect residents' access to groundwater. Domestic wells are not as equipped as commercial wells, and up to 500 feet of drawdown estimated by the Guyton report can cause residents' wells to dry up. Wichi Wolf in her article in *The Austin Chronicle* (3 April 2015) cited Loui Bond, the Texas Parks and Wildlife editor who lives within a mile and a half from where EP located its wells. Based on Guyton report results, water levels in Bond's neighborhood would drop by 350 feet, while her well is almost 330 feet deep. Concerned by the situation she discovered that the cost for a 700-foot well is $28,000. However, EP contested the results of this report, claiming that the company is monitoring their pumping impact on surrounding wells, and aims to share that information to "build a scientifically based model of how much water is truly available" (Wolf, 2015).

Although the speed of growth in Austin's neighboring areas puts great pressure on groundwater resources and the regulatory entities, the evidence shows that the lack of

single-source geo-hydrologic data of this section of The Trinity Aquifer is an obstacle for the authorities to be able to make decisions on a scientific basis. In the EP case also, as Brian Smith, Senior hydrologist at BSEACD stated, there is not enough data available to determine possible decline in nearby wells (Tavarez, 2015).

Gathering data on aquifer behavior could be a long and expensive process. However, based on the available information on slow recharge patterns of the Trinity Aquifer, conservative use of this aquifer is highly recommended, said Dianne Wassenich, program director of the San Marcos River Foundation (Arguello, 2015).

The passage of HB 3405 has been a significant sign that the Texas legislature is willing to protect groundwater resources and plan for their sustainable use. However, the most significant change is seen in Wimberley residents' approach to the private property concept. Historically, landowners preferred to reject government's involvement in regulating their access to natural resources available on or under their lands. The EP case has been one of the rare events where residents asked for further regulation and limitation of their private property rights for the sake of protecting their rights to groundwater and for the sake of the environment.

This case study was an outstanding example of the rule of capture's inadequacy for long-term sustainability of groundwater resources for the next generation of humans and non-humans in Texas. This study is a call for legislative action to cover the existing unregulated areas with existing or new conservation district authorities. This case study is also a call for scientists who are involved in groundwater policy making to apply further precaution in their scientific calculations, especially when uncertainty exists.

V. METHODOLOGY

The research questions developed for this study lead to the decision that the interview method best fits the purposes of this thesis. The interview questions were formulated based on the literature review analysis and conversations with local citizens regarding the groundwater issues in Wimberley Valley in the Texas Hill County. The questions were developed with the main area of interest in mind: policy considerations for sustainable use of groundwater in Texas. The interviews were conducted under supervision and approval of the Texas State University Institutional Review Board, Approval # 2015U1100.

Research Questions

This research seeks to answer the following questions:

RQ1: How should the rule of capture be modified? What would a better law look like?

RQ2: Will the rule of capture be adequate to address possible future environmental problems and water shortages in Texas? If not, is overturning the rule of capture, as it relates to groundwater, a realistic option in the State of Texas?

Interview Design and Administration

This research uses two qualitative research methods: a semi-structured face-to-face or in-depth interview and case study. The qualitative approach includes a vast range of methods "making possible research topics and questions as vast as our imagination" (Hesse-Biber and Leavy, 2006, 19). The case-study presents a recent water conflict in the

Texas Hill Country. The analysis of elements of the case-study and stakeholders' behavior created more insight into current groundwater management strategies and local aspects of it.

Face-to-face interviews were chosen as the primary research method because of the possibility of conversation between interviewer and interviewee offered by this type of qualitative method. Hesse-Biber and Leavy (2006) state that "in-depth interviews are issue oriented" (120). In other words, the in-depth interview method is useful when there is particular topic on which the researchers want to focus in order to obtain information about the topic from the individual participants.

The interview questions reflect the concern and ambiguity emerging from the literature review and the case study chapter, aiming to address these issues and gain recommendations for a more effective policy proposal. Email, skype and phone-call were also considered as alternative interview tools whenever the possibility of conducting a face-to face interview was lacking.

The participants are members of various institutional and scientific entities involved in groundwater management or policy in the state of Texas. Moreover, the researcher's membership in a Facebook closed group created to discuss water issues complemented the data gathering goals for this study. The Facebook page has been designed by a citizen in Wimberley, with the objective of giving residents the possibility of sharing their thoughts and experiences concerning the water management strategies and policies at both local and state levels.

The interview questions are designed based on the five conceptual frameworks represented in the following tables. These sections include questions about the rule of

capture, Groundwater Conservation Districts (GCDs), Groundwater Management Areas (GMAs), Future Development, Population Growth, and Groundwater Availability, and Future of groundwater policy.

Rule of capture	
• Definition • History • Mitigation consideration • Sustainability	• Do you know what the “rule of capture” is? Does the rule of capture consider a mitigation plan for unintended consequences? • The Supreme Court of Texas has always reaffirmed the rule of capture following the history of this rule; how can the legislature prevent a dispute from reaching the court? Some have proposed that the Legislature create a special court for water issues. What do you think of this idea? • How can the rule of capture protect the rights of individual citizens against corporate water withdrawal? • Do you think the rule of capture will be adequate to address possible future environmental problems and water shortage?

Groundwater Conservation Districts (GCDs)	
• Functionality • Funding • Collaboration • Data collection	• Are you familiar with the phrase "close the loophole" when it is applied to water in Texas? • If GCDs are to be the vehicle through which the rule of capture is to be addressed, then what policies would "close the loophole" that now exists? • Considering the fact that a GCD is the state's preferred method of GW management, do you have view about why the Legislature has not still covered the unregulated areas by GCDs? • How well do GCDs work in Texas? Can you name one (some) that works well? Can you name one (some) that do not work well? What are some things they do well? What are some limitations or failings? • How are GCDs funded? Can you think of a better plan for funding GCDs? • Can fund sharing be a good idea for GCDs working on the same aquifer? • Do you know how GCDs obtain aquifer data? Do GCDs with shared authority on a common aquifer gain the aquifer data from a single neutral provider of data?

Groundwater Management Areas (GMAs)	
• Coordination strategies	• In what ways can a Groundwater Management Area improve the collaboration among GCDs who share the same aquifer?

Future Development, Population Growth, and Groundwater Availability	
• Groundwater marketing • Protection of individual right to groundwater against corporate water withdrawal	• What are your recommendations for better protecting individuals' rights to water in the context of groundwater marketing under the rule of capture? • Should development be restricted by requiring developers to procure water rights first? What laws and regulations are out there to restrict water usage and conserve groundwater in the predicted drought years ahead? How would these regulations then be mandated and enforced? • Some citizens believe that there is disconnect between limited water resources and the very restricted authority granted local governments to slow the pace of growth, particularly in critical groundwater management areas such as in most of Hays County and the Hill Country. It seems that the Texas Local Government Code stands like a great wall, virtually

	shielding growth against any consideration for water sustainability at the local level. How would you explain this issue?
Future of groundwater policy	
• Perspective • Recommendations	• Do you think overturning the rule of capture as it relates to groundwater is a realistic option in the State of Texas? • If you were making recommendations to the Legislature regarding modification or replacement of the rule of capture, what would they be?

All participants were contacted by email or phone calls to schedule an interview appointment. They were all asked the same list of questions. However, based on their expertise and professional fields, participants had the possibility to expand on specific questions. The average duration of each interview was about 40 to 50 minutes and the place of interview was chosen based on the preferences of interviewees.

Advantages of interview

Face-to-face interviews, also known as "in-person" interviews, have long been a popular technique in the field of qualitative research methods. This type of qualitative technique is usually used when the conversation and interaction between interview and interviewee helps to maximize the quality of data collected. Due to synchronous communication, no other interview method except face-to-face interviews can take

advantage of social cues such as intonation, voice and body language (Opdenakker, 2006). The social cues of the participants can provide the interviewer with extra information that can enrich the verbal responses of the interviewee.

Another advantage of face-to-face interviewing is the possibility of using recording devices to gather more precise information. This also provides the interviewer the possibility to transcribe the information and go back to the source whenever it is required. However, recording the interviewees' voices should occur with the participant's permission.

Face-to-face provides the opportunity for probing giving the interviewer the possibility of getting more details whenever needed (Dialsingh, 2008). This method is designed to obtain subjective information that the interviewees might desire to add. Moreover, the presence of the interviewer provides the chance for the interviewee to ask for clarification on some of the topics and questions. Face-to-face interviews also minimize the chance of nonresponse items, which can occur using survey methods.

Disadvantages of interview

One common disadvantage associated with using interview as a qualitative research technique is the limited time for interviewees to think about their responses. While spontaneity of answers might increase the possibility of obtaining honest and less biased responses, it may also result in less accurate responses. One way to reduce this effect and obtain more thoughtful answers is to email the questions to the interviewees a few days before the interview appointment, giving them the possibility of thinking about the responses. However, this may reduce the level of spontaneity of the answers. Depending on the objectives of the project, the interviewer can choose to evaluate

whether spontaneity is essential or if it can be exchanged in favor of obtaining more thoughtful responses.

Dialsingh (2006) discusses that visibility can count as a disadvantage in face-to-face interviews, when the interviewer's behavior guides the interviewee's response in a particular direction. This effect is normally reduced depending on the interviewer's professional level and his/her awareness of this effect.

Using recording devices for face-to-face interviews, although it has many advantages, can cause some undesired results. The malfunction of the recording device is one situation where the interviewer risks losing all the information, especially if no notes were taken during the interview. Another disadvantage of recording is the time required to transcribe the recorded information. Bryman (2001) states that it can take up to six hours to transcribe one hour of recorded information (Cited by Dialsingh, 2006).

Privacy is also a concern in the face-to-face interview data collecting method (Dialsingh, 2006). In addition, in-person interviews often require longer time than other types of qualitative techniques such as surveys. One other possible disadvantage of face-to-face interviews is the cost. Sometimes this method can be expensive depending on the size of the sample and the amount of information that needs to be collected.

For this research, the face-to-face interview is considered to be the best method to answer the research questions. The reason is that the researcher knew many of the participants prior to this research. Moreover, many of the parties were already involved in the case because of their professional roles and/or as citizen activists. Overall, the advantages of the face-to-face interview method exceed the disadvantages in the case of this study.

VI. RESULTS

This chapter discusses the results obtained by analyzing the completed interviews. The purpose of these interviews is to evaluate the opinions of professionals and stakeholders involved in groundwater management in South-Central Texas. The questions relate to the groundwater law in Texas, rule of capture, and management strategies.

Description of Results

A total of seven face-to-face interviews were conducted. The data was collected by a sound recording device and later transcribed by the interviewer. The participants belong to various fields related to groundwater management in Texas. The face-to-face interview provided the interviewer and interviewees with the chance to be involved in an in-depth discussion, essential to the purpose of this thesis. All participants showed particular interest in the discussion, and they answered all of the interview questions.

Rule of capture. Four questions of 18 were about the rule of capture and its past and eventual future role in groundwater availability in Texas.

- Do you know what the "rule of capture" is? Does the rule of capture consider a mitigation plan for unintended consequences?

The results show that all participants were completely familiar with the rule of capture and the exceptions considered by this rule (wasteful, malicious, land subsidence). The majority believe that the rule of capture, outside of a GCD, does not consider any mitigation plan for unintended consequences to people or the environment. According to Vanessa Williams, an environmental attorney involved in the Electro Purification's case, the rule of capture is a way to assess the liability rather than a policy to manage the

groundwater resources. John Dupnick, the general manager at Barton Spring Edwards Aquifer conservation district stated the rule of capture as a "tort or "no-liability" law; any mitigation would cause the modification of this rule."

- The Supreme Court of Texas has always reaffirmed the rule of capture following the history of this rule; how can the legislator prevent a dispute from reaching the court? Some have proposed that the Legislature create a special court for water issues. What do you think of this idea?

Some of the respondents affirmed that they do not have the required expertise to answer this question. However, the overall reaction to this question indicates that the Legislature cannot prevent a dispute from reaching the Court. Dianne Wassenich from San Marcos River foundation believes that the Court wanted the Legislature to take an action to address the issue but the Legislature has not taken any decisive action to do so. She indicates to a discord among the legislators, who prefer to keep the groundwater management at the local level. The other group favors the marketing of groundwater around the state. Will Conley, the Hill Country representative affirms that the scientific uncertainty in evaluation of the groundwater resources has been the reason for the Court's and the Legislature's hesitation to address this issue. However, with today's available technology, all they need to do is to encourage scientific research about the state's aquifers to be able to more accurately and adequately develop policies for control and conservation of the groundwater in Texas.

The second part of the question asks about the eventual advantage of creating a special court for water issues. The majority believes that this idea does not fit the political

and geographical characteristics of the state of Texas. Andrew Sansom, the executive director of the Meadows Center for Water, believes that "Texas is too complex as a society to dedicate a whole system to a court for water." The state of Colorado is a good example where a water court exists and works well. In comparison with Texas, Colorado has a smaller population, more rural areas, and a less complex society than that of Texas, where "water is a crucial issue given its scarcity and its importance for agriculture." John Dupnik states that a water court might be useful in cases of disputes between a GCD and a landowner. These disputes sometimes occur because of the restrictions that a GCD imposes in order to meet the DFC, but might be perceived as violation of private property based on the rule of capture.

- How can the rule of capture protect the rights of individual citizens against corporate water withdrawal?

The unanimous agreement among the respondents shows that the rule of capture is not able to protect the individual residents' rights to groundwater against corporate water production. The only possibility for the contrary to happen is to prove one of the three exceptions of the rule of capture (malicious use, wasteful use, land subsidence). However, historical evidence shows that this has rarely been possible to prove. The majority of interviewees believe that the only way to protect individual rights is acting through a GCD, wherever one exists.

- Do you think the rule of capture will be adequate to address possible future environmental problems and water shortage?

All participants are convinced that the rule of capture alone does not encourage the sustainability of groundwater resources and it is not able to address possible future environmental problems and water scarcity in Texas.

Groundwater Conservation Districts (GCDs). Another eight questions were designed to capture information and address concerns about the Groundwater Conservation Districts (GCDs).

- Are you familiar with the phrase "close the loophole" when it is applied to water in Texas?

All answers to this question were affirmative.

- If GCDs are to be the vehicle through which the rule of capture is to be addressed, then what policies would "close the loophole" that now exists?

The majority of answers recognizes politics as an obstacle to the creation of GCDs that cover the unregulated areas in Texas. Andrew Sansom believes that "the reason we have places that are not covered by districts is people oppose it and the Legislature is very reluctant to take on local people unless there is a crisis; I would argue

that there is a crisis but it may not be manifest locally." Rene Barker, a USGS former hydrologist, states that GCDs have not been created to close the loopholes because of time, funds and political bias. However, once a GCD is created, water conservation and closing the loopholes will depend on the policies that the board members adopt. A newly-created board may adopt pro-development or pro-conservation policies. In the same line, Vanessa Williams states that even having a GCD in place does not guarantee the sustainable use of groundwater because GCD board issue production permits which go way over the DFC of the aquifer. Will Conley suggests that local people should decide to create a GCD wherever is a white zone. He points to the recent example of EP's case in Hays County where community action led to the legislative decision to cover the unregulated zone over the Trinity Aquifer with an existing GCD. However, John Dupnik believes that the creation of a GCD is not enough to close the loopholes; depending on the availability of funds, the GCDs function differently. He thinks that the EP case was extraordinary because it was a reverse case, which rarely happens in the context of Texan culture; usually local land owners do not want government infringement on the use of their private property. He thinks that this case is an effective example to illustrate that the government overlay is the best tool for protecting citizen's private property rights and the sustainability of groundwater use in Texas.

- Considering the fact that a GCD is the state's preferred method of GW management, do you have a view about why the Legislature has still not covered the unregulated areas by GCDs?

The overall responses to this question indicate that the problem has cultural roots. John Dupnik affirms that the majority of GCDs are created by the Legislature. Dianne Wassenich thinks that the Legislature wants to see if local people can and will take charge to protect their resources. However, in many cases, the local residents are opposed to the creation of a GCD because they do not want to pay higher taxes or have government control over how to use their private property. Many are concerned that a GCD may want them to locate a meter for their wells or restrict their use.

- How well do GCDs work in Texas? Can you name one (some) that work well? Can you name one (some) that do not work well? What are some things they do well? What are some limitations or failings?

All respondents believe that GCDs in Texas have different qualities of performance because of various political, financial and geographic reasons. The lack of proper funding is the main issue for GCDs with low performance. All of the old districts in the Panhandle, in addition to BSEACD, are good ones (Dupnik and Sansom). They have a crucial responsibility because of the large amount of agriculture in the area, which was the first threat to groundwater availability, and secondly, because of the industrial use. Dupnik believes that they are effective because of the procedure involved in their

creation. They delineated the boundaries of an aquifer and they petitioned to create GCDs consistent with the designated needs, therefore they created multi-county aquifer scale districts. Moreover, the philosophy that each district adopts influences its performance; Some of them believe that they are responsible for protecting the groundwater and some believe they should sell it as quickly as possible (Sansom).

- What are your recommendations for GCDs to work more efficiently?

All respondents believe that GCDs should improve their data collection and research. For this purpose, they all believe that adequate funding is the key for GCDs to be able to use more science for their decision-making processes. Many of the aquifers need updated modeling for their interflow and interaction with other underground resources. Moreover, GCDs need to take more precaution in determining their DFCs (Williams).

Dupnik presents the idea of bringing all GMAs under one entity that provides support and technical resource to them. He proposed the idea of "Groundwater Management Area Councils" in his graduate thesis by using SB2 as the source. GMAC can have the power to decide how to allocate water through cohesive and coordinated management among districts.

- How are GCDs funded? Can you think of a better plan for funding GCDs?

GCD's are either tax-based or fee-based, rarely both, depending on the procedure through which they were created. The majority of participants believe that alternative funding methods should be identified to help GCDs to generate sufficient revenue. John Dupnik believes that GCDs' current funding authority should be extended to include both types of funding methods to be able to make up the shortfalls. This may especially help districts that cover small areas to generate enough revenue. Dupnik states that the water code includes both methods, but the Legislature usually decides based on what type of funding is available.

Chapter 36 exempts many uses of groundwater. Wells for residential, oil, gas and agricultural uses are exempt, which does not help GCDs to generate enough revenue (Sansom). If the Legislature decides to remove all these exemptions, GCDs can collect a decent revenue to invest in research and modeling.

- Can fund sharing be a good idea for GCDs working on the same aquifer?

The general answer indicates a positive response to the question. However, fund-sharing for GCDs who share an aquifer does not seem realistic within the current cultural and political context of Texas. Andrew Sansom, John Dupnik, and Vanessa P. Williams believe that regionalization of groundwater management would lead to a better organization of revenue distribution. However, fund-sharing can create some conflict as shared aquifers that have multiple authorities are all funded differently and have different

rates of taxation; in the districts with the higher taxation rate, the tax payer would not agree to subsidize the residents of another district with a lower tax rate (Dupnik).

- Do you know how GCDs obtain aquifer data? Do GCDs with shared authority on a common aquifer gain the aquifer data from a single neutral provider of data?

According to respondents who have the expertise to answer this question, the Texas Water Development Board (TWDB) periodically collects data about groundwater resources and makes results available to all GCDs. However, during the last several Legislative sessions, the Legislature has cut the budget for science (Sansom), which has created difficult conditions for TWDB to conduct research about the aquifers in Texas.

GCDs also depend on the expertise of their board members to gather data about the groundwater resources within the area of their jurisdiction and share their data with other GCDs, especially with those who share the same aquifer. However, funding shortages remain the main issue for GCDs and determine the conservation districts' abilities to hire experts in groundwater to conduct research and collect data.

Groundwater Management Areas (GMAs) - The following question is designed to obtain information about GMAs and their roles in managing groundwater resources by improving the collaboration among GCDs.

- In what ways can a Groundwater Management Area improve the collaboration among GCDs who share the same aquifer?

Most interviewees responded that GMAs can improve the collaboration among GCDs by encouraging them to participate in their meetings. According to Andrew Sansom, for GMAs to work more efficiently, GCDs' boundaries should change from political lines to aquifer boundaries. For example, for the Western Edwards Plateau, there are several districts with different philosophies and different capabilities.

John Dupnik states that GCDs have to participate in GMAs' periodical meetings, but GCDs are not required to put any effort in their participation in the meetings and in their collaboration with other GCDs who work on a shared aquifer. Dupnik believes that GCDs should have the responsibility to create a management plan and to update it every five years. They should be required to meet and share their experiences with other districts. Their plan should be approved by an entity that has authority over their activities. GMA does not have complete authority to require these regulatory procedures, but the Texas Legislature can do this through the implementation of the idea of GMACs, extracted from SB2.

Future Development, Population Growth, and Groundwater Availability- The next three questions aim to obtain information and recommendations that might be useful for policy makers to consider in their future water-planning decisions.

The following two questions were selected from a list of questions that local residents in Wimberley in the Texas Hill Country proposed to add to the list of questions for interviews. Both of the questions deal with water policy and future development in Hays County, so the respondents chose to combine their answers to these two questions.

- Should development be restricted by requiring developers to procure water rights first? What laws and regulations are out there to restrict water usage and conserve water for the predicted drought years ahead? How these regulations then are mandated and enforced?

- Some citizens believe that there is disconnect between limited water resources and the very restricted authority granted local governments to slow the pace of growth, particularly in critical groundwater management areas such as in most of Hays County and the Hill Country. It seems that the Texas Local Government Code stands like a great wall, virtually shielding growth against any consideration for water sustainability at the local level. How would you explain this issue?

State legislators have decided to give the groundwater responsibility to GCDs, so if the development goes beyond just residential use, the developer needs to ask for a permit from the GCD with the authority on that specific area (Conley). Dianne Wassenich states that water rights should be required but in reality "there is not water rights for sale very much anymore; all large cities are already fighting over the use of wastewater." She and Vanessa Williams believe that more authority must be given to the counties to engage in land use planning and water allocation. Counties and GCDs can control the size of tracts based on the number of wells a county can have, but if a subdivision is importing water from outside, then these entities do not have any authority to control and eventually oppose the use of this water. However, in various cases, the Legislature has encouraged

the import of water from outside as a solution to facilitating development in the areas facing water shortages. For example, when the Legislature passed a request for the creation of a municipal utility district on the Blanco River, the law stated that the developers could not use the groundwater and had to provide water from somewhere else (Sansom).

John Dupnik confirms the fact that the Texas Legislature tends to solve the water availability issues by encouraging the transfer of water from places where water is available to those where water is lacking. The role of GCDs varies based on the inclinations of their board members; some are development-friendly so they might not offer enough protection for individuals and the environment. For example Post Oak Savannah groundwater conservation district has a market-friendly approach, which encourages the transfer of water. On the other hand, there are GCDs that encourage conversation and they tend to block water transfers, such as Lost Pines conservation district. oth districts share the Carrizo-Wilcox Aquifer.

- What are your recommendations for better protecting individuals' rights to water in the context of groundwater marketing under the rule of capture?

All participants believe that the rule of capture outside the jurisdiction of a GCD cannot protect the rights of individuals to groundwater against major producers of groundwater. They propose that the Legislature cover the unregulated areas with existing GCDs or create new ones to protect groundwater resources in these regions. Representative Conley believes that the population of Texas is projected to grow

drastically in the near future, and as a result, water suppliers will impose more pressure on underground resources. Therefore, if the policy makers do not implement proper strategies to manage these natural resources, the state will face serious water shortage.

- Do you think overturning the rule of capture as it relates to groundwater is a realistic option in the State of Texas?

The majority of respondents believe that overturning the rule of capture is not a realistic option. However, John Dupnik states that there are not many places in Texas where the only rule is the rule of capture. However, the rule of capture is archaic because it is based on the fact that the groundwater movement is "secrete and occult," which is not valid anymore, due to advances in science and technology (Dupnik). At some point, the Legislature will try to regionalize or somehow broaden districts' authority; only a regional board not involved in emotions can adequately manage the groundwater resources (Williams).

- If you were making recommendations to the Legislature regarding modification or replacement of the rule of capture, what would they be?

The following list summarizes the interviewees' recommendations to the Texas legislature in order to improve the groundwater policy and management in Texas:

- To adopt strategies that promote the conjunct management of surface and underground water.

- To bring the unregulated areas under the jurisdiction of an existing or new GCD.
- To replace the rule of capture with reasonable use as an alternative to determine liability.
- To regionalize groundwater management by creating GMACs to improve the organization and collaboration among GCDs.
- To increase funds for investing in scientific research and data collection about the groundwater sources to update the groundwater availability models.
- To keep a perspective of government that best represents the community while protecting the environment and natural resources.

VII. POLICY RECOMMENDATIONS

The following section offers a series of recommendations to answer the two research questions designed for the purposes of this thesis:

RQ1: How should the rule of capture be modified? What would a better law look like?

RQ2: Will the rule of capture be adequate to address possible future environmental problems and water shortages in Texas? If not, is overturning the rule of capture as it relates to groundwater a realistic option in the State of Texas?

These recommendations are offered based on political and social feasibility to improve the current groundwater management system in Texas. Information about groundwater regulation and management was collected from a selection of academic articles and books, the development of a case-study, and face-to-face interviews that were conducted to cover the uncertainties that emerged from the literature review.

1. Conjunctive management for surface and groundwater is identified as the best policy design for managing water sources. It is recommended that the Texas legislature pass laws to eliminate the disconnect that has been created from the separation of surface and underground water law in Texas. Integration of surface and groundwater under a single definition of water sources might be the first step in eliminating this gap.
2. GCDs need to be provided with alternative funding methods to collect sufficient revenue to improve their performances for water conservation and sustainable planning. For this purpose, the legislation should provide all GCDs with the authority to collect funds by using both the tax and fee

methods of fund collection to generate the revenue required to improve their performances.

3. Another recommendation is the regionalization of groundwater management based on hydro-geological boundaries rather than political or county-based boundaries. This can occur by maintaining GCDs within the framework of GMAs with some modification in management procedures such as the introduction of GMA councils. GMAC can improve the coordination of GCDs, especially the ones with authority over shared underground resources. This strategy can improve the current management system by addressing local-scale political disagreements and self-interest, insufficient funding, and hydrological disconnects (Dupnik, 2012).
4. Groundwater scientists need to apply further precautions to deal with uncertainties in groundwater evaluations and simulations. Their evaluations should be conservation-oriented rather than market-oriented.
5. Simple design of conservation standards is recommended. Simple standards would be easy to manage and implement (Glennon, 2002).
6. Unregulated areas should be covered under existing or new GCDs' authority based on the hydro-geological characteristics.
7. Meters should become required for all domestic and commercial wells in order to improve the accuracy in data collection. As a result, scientific institutions can decrease uncertainty by providing more accurate groundwater models and simulations.

8. Currently, the wells used for domestic/livestock and oil/gas exploration and coal mining are exempt under chapter 36 of the Texas Water Code. It is recommended to remove these exemptions in order to improve revenue collection and data gathering, and for long-term sustainability management purposes.

VIII. CONCLUSION

The literature review and interview results demonstrate that the overturn of the rule of capture does not seem realistic in the current political and cultural context of Texas. “Existing groundwater pumpers represent a powerful political force in every state, one with sufficient leverage to block any reform effort that tramples on their interests” (Glennon, 2002, 216). The majority of political scientists believe, Glennon states, that in any political context, if there is a small group of aggressively committed voters against a large group of slightly engaged voters, the legislative vote will favor the small group’s position (2002).

There is no reasonable justification for the Texas Legislature to continue managing the state groundwater resources through the rule of capture, a non-liability law that allows a landowner to drain an aquifer unlimitedly, while the consequences of resource degradation are shared among all residents who use the same resource. By residents, it is not intended to include only humans, but also all the non-human species whose lives depend on the same resources and contribute in providing ecological services to the community (Leopold, 2013).

In the state of Texas, the surface water is highly regulated by prior appropriation doctrine while the groundwater is weakly protected by the rule of capture, sometimes even with GCDs in place. However, rivers, lakes, streams and creeks around the state suffer from this disconnect in law and risk depletion in view of future climate change. This disconnected vision of surface and groundwater originated in a historical misunderstanding of geo-hydrology in Texas, where the law treats the groundwater and

surface water as two independent resources. However, current science and technology leave no doubt that the separate management of surface and underground water is contributing to resource depletion leading to a water-scarce future.

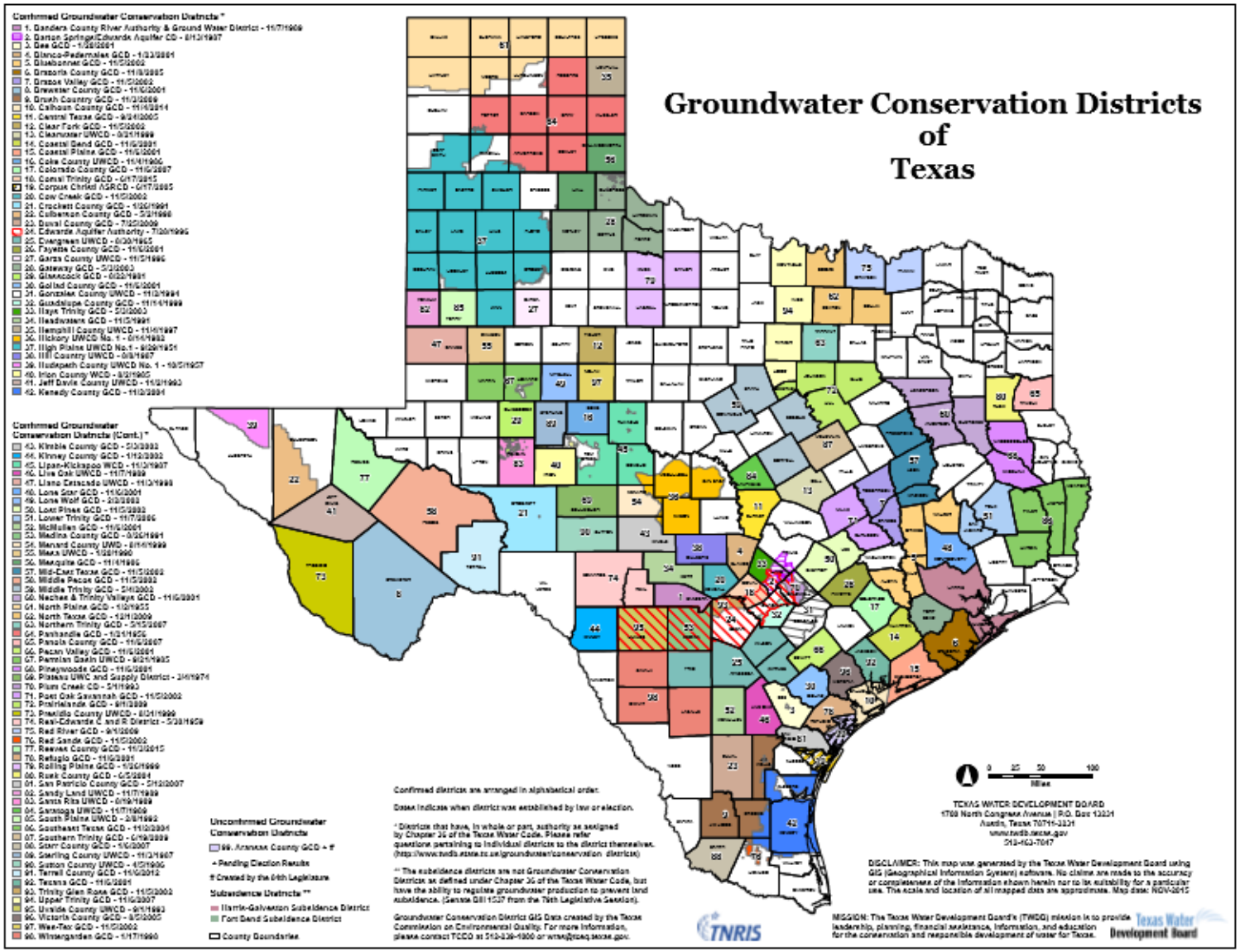
The rule of capture has proven to be unscientific and ineffective in managing groundwater resources and the Supreme Court of Texas has often failed to eliminate the gap between science and law. The Court, instead, decided to vest the Legislature with the authority to manage the state's groundwater resources by making modifications in the law, if necessary. As a result, the Texas legislature has created GCDs and GMAs to improve the management of groundwater and perhaps eliminate the gap between the surface and underground water regulation. The preference for local management by the Legislature may be because of the geographically vast size of Texas and the geo-cultural diversities across the state (Conley).

Although conservation districts have proven effective for the protection of aquifers in some regions, such as in the Texas Panhandle, this management strategy has resulted in less effective protection of groundwater in other places such as Hays County. The restricted power of GCDs under land development policies, insufficient funding, disagreements between the board members and the lack of effective coordination among districts are identified as the main reasons that impede GCD's improvement of their efficiency. Moreover, many of these districts have been created along political boundaries of counties rather than based on the aquifer boundaries (Dupnik, 2012).

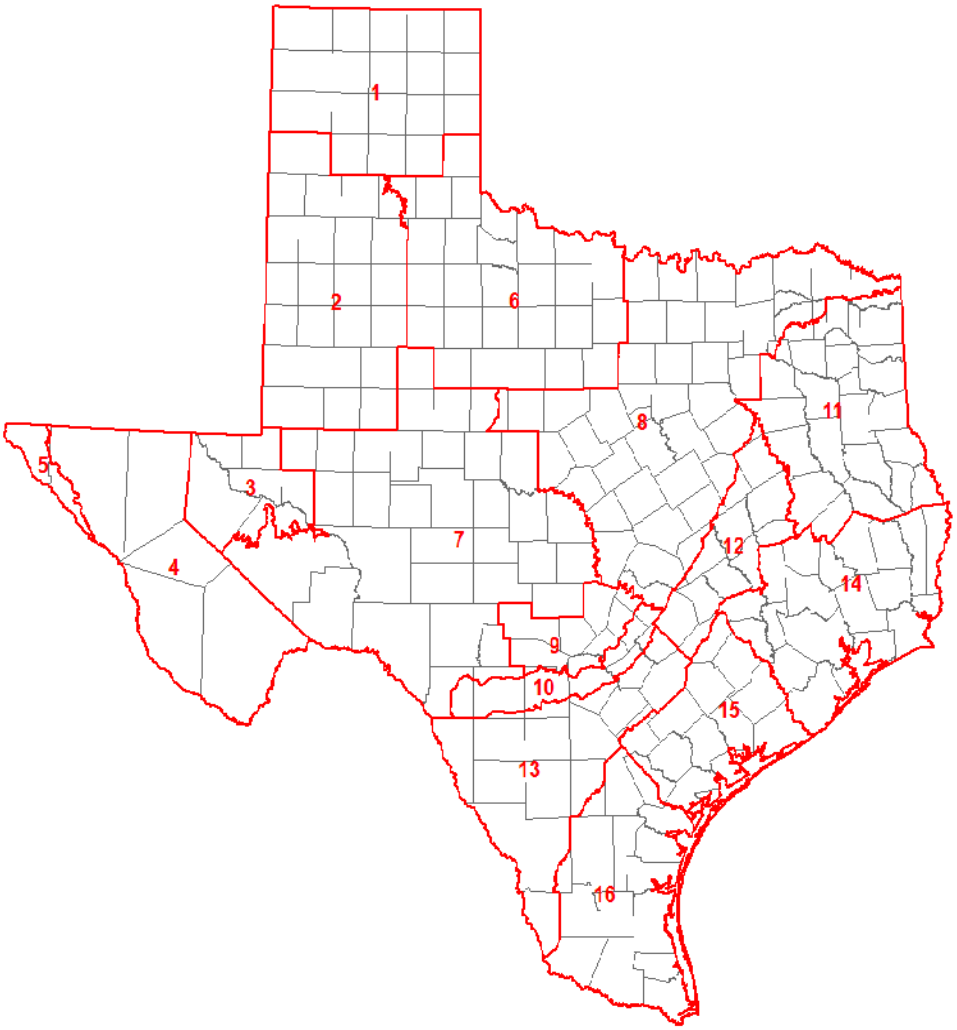
In conclusion, in order to address the groundwater management issue within the current institutional framework, which is likely to continue to include the rule of capture, policy makers can make a choice to: 1) provide GCDs with the possibility of using both

tax and fee methods for revenue collection; 2) encourage scientists to include more precautions in their estimates; 3) increase the funding for research with focus on major groundwater sources and their interactions with other water resources in the state; 4) require the monitoring of exempted wells by requiring meters in order to improve the accuracy of collected data and groundwater models.

APPENDIX SECTION


Groundwater Conservation Districts
of
Texas
Confirmed Groundwater Conservation Districts *
1. Bandera County River Authority & Ground Water District - 11/7/1989
2. Barton Springs/Edwards Aquifer CD - 8/13/1987
3. Bee GCD - 1/28/2001
4. Blanco-Pedernales GCD - 1/3/2001
5. Bluebonnet GCD - 11/5/2002
6. Brazoria County GCD - 11/8/2005
7. Brazos Valley GCD - 11/5/2002
8. Brewster County GCD - 11/6/2001
9. Brush Country GCD - 11/3/2009
10. Calhoun County GCD - 11/4/2014
11. Central Texas GCD - 9/24/2005
12. Clear Fork GCD - 11/2/2002
13. Clearwater UWCD - 9/25/1999
14. Coastal Bend GCD - 11/6/2001
15. Coastal Plains GCD - 11/5/2001
16. Coke County UWCD - 11/4/1996
17. Colorado County GCD - 11/6/2007
18. Comal Trinity GCD - 6/17/2015
19. Corpus Christi ASRCD - 6/17/2005
20. Cow Creek GCD - 11/5/2002
21. Crockett County GCD - 11/2/1991
22. Culberson County GCD - 5/2/1998
23. Duval County GCD - 7/25/2009
24. Edwards Aquifer Authority - 7/20/1996
25. Evergreen UWCD - 6/30/1965
26. Fayette County GCD - 11/6/2001
27. Garza County UWCD - 11/2/1996
28. Gateway GCD - 5/3/2003
29. Glasscock GCD - 6/22/1981
30. Goliad County GCD - 11/5/2001
31. Gonzales County UWCD - 11/2/1991
32. Guadalupe County GCD - 11/14/1999
33. Hays Trinity GCD - 5/3/2003
34. Headwaters GCD - 11/5/1991
35. Hemphill County UWCD - 11/4/1997
36. Hickory UWCD No. 1 - 6/14/1982
37. High Plains UWCD No.1 - 9/26/1951
38. Hill Country UWCD - 5/3/1967
39. Hudspeth County UWCD No. 1 - 10/21/1957
40. Irion County WCD - 8/2/1960
41. Jeff Davis County UWCD - 11/2/1993
42. Kenedy County GCD - 11/2/2004
Confirmed Groundwater Conservation Districts (Cont.) *
43. Kimble County GCD - 5/3/2003
44. Kinney County GCD - 11/2/2002
45. Lipan-Kickapoo WCD - 11/2/1987
46. Live Oak UWCD - 11/7/1999
47. Llano Estacado UWCD - 11/2/1998
48. Lone Star GCD - 11/6/2001
49. Lone Wolf GCD - 2/2/2002
50. Lost Pines GCD - 11/5/2002
51. Lower Trinity GCD - 11/7/2006
52. McMullen GCD - 11/5/2001
53. Medina County GCD - 9/25/1991
54. Menard County UWD - 8/14/1999
55. Mesa UWCD - 1/28/1998
56. Mesquite GCD - 11/4/1998
57. Mid-East Texas GCD - 11/5/2002
58. Middle Pecos GCD - 11/5/2002
59. Middle Trinity GCD - 5/3/2003
60. Neches & Trinity Valleys GCD - 11/6/2001
61. North Plains GCD - 11/2/1955
62. North Texas GCD - 11/1/2009
63. Northern Trinity GCD - 5/15/2007
64. Panhandle GCD - 1/31/1978
65. Panola County GCD - 11/5/2007
66. Pecan Valley GCD - 11/5/2001
67. Permian Basin UWCD - 9/21/1985
68. Pineywoods GCD - 11/6/2001
69. Plateau UWC and Supply District - 3/4/1971
70. Plum Creek CD - 5/1/1993
71. Post Oak Savannah GCD - 11/5/2002
72. Prairielands GCD - 9/1/2009
73. Presidio County UWCD - 8/21/1999
74. Real-Edwards C and R District - 5/28/1969
75. Red River GCD - 9/1/2009
76. Red Sands GCD - 11/5/2002
77. Reeves County GCD - 11/2/2015
78. Refugio GCD - 11/6/2001
79. Rolling Plains GCD - 1/25/1999
80. Rusk County GCD - 6/5/2004
81. San Patricio County GCD - 5/12/2007
82. Sandy Land UWCD - 11/7/1989
83. Santa Rita UWCD - 6/19/1999
84. Saratoga UWCD - 11/7/1998
85. South Plains UWCD - 2/5/1992
86. Southeast Texas GCD - 11/2/2001
87. Southern Trinity GCD - 6/19/2009
88. Starr County GCD - 11/6/2007
89. Sterling County UWCD - 11/2/1987
90. Sutton County UWCD - 11/5/1999
91. Terrell County GCD - 11/6/2012
92. Texana GCD - 11/6/2001
93. Trinity Glen Rose GCD - 11/5/2002
94. Upper Trinity GCD - 11/6/2007
95. Uvalde County UWCD - 9/1/1993
96. Victoria County GCD - 5/5/2005
97. Wes-Tex GCD - 11/5/2002
98. Wintergarden GCD - 11/7/1990
Unconfirmed Groundwater Conservation Districts
99. Aransas County GCD + #
+ Pending Election Results
# Created by the 84th Legislature
Subsidence Districts **
Harris-Galveston Subsidence District
Fort Bend Subsidence District
County Boundaries
Confirmed districts are arranged in alphabetical order.
Dates indicate when district was established by law or election.
* Districts that have, in whole or part, authority as assigned by Chapter 36 of the Texas Water Code. Please refer questions pertaining to individual districts to the district themselves. (http://www.twdb.state.tx.us/groundwater/conservation_districts)
** The subsidence districts are not Groundwater Conservation Districts as defined under Chapter 36 of the Texas Water Code, but have the ability to regulate groundwater production to prevent land subsidence. (Senate Bill 1537 from the 76th Legislative Session).
Groundwater Conservation District GIS Data created by the Texas Commission on Environmental Quality. For more information, please contact TCEQ at 512-239-4600 or wrwp@tceq.texas.gov.
0 25 50 100
Miles
TEXAS WATER DEVELOPMENT BOARD
1700 North Congress Avenue | P.O. Box 13231
Austin, Texas 78711-3231
www.twdb.texas.gov
512-463-7847
DISCLAIMER: This map was generated by the Texas Water Development Board using GIS (Geographical Information System) software. No claims are made to the accuracy or completeness of the information shown herein nor to its suitability for a particular use. The scale and location of all mapped data are approximate. Map date: NOV-2015
TNRIS
MISSION: The Texas Water Development Board's (TWDB) mission is to provide leadership, planning, financial assistance, information, and education for the conservation and responsible development of water for Texas.
Texas Water Development Board

2. Groundwater Management Areas-Texas Water Development Board



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