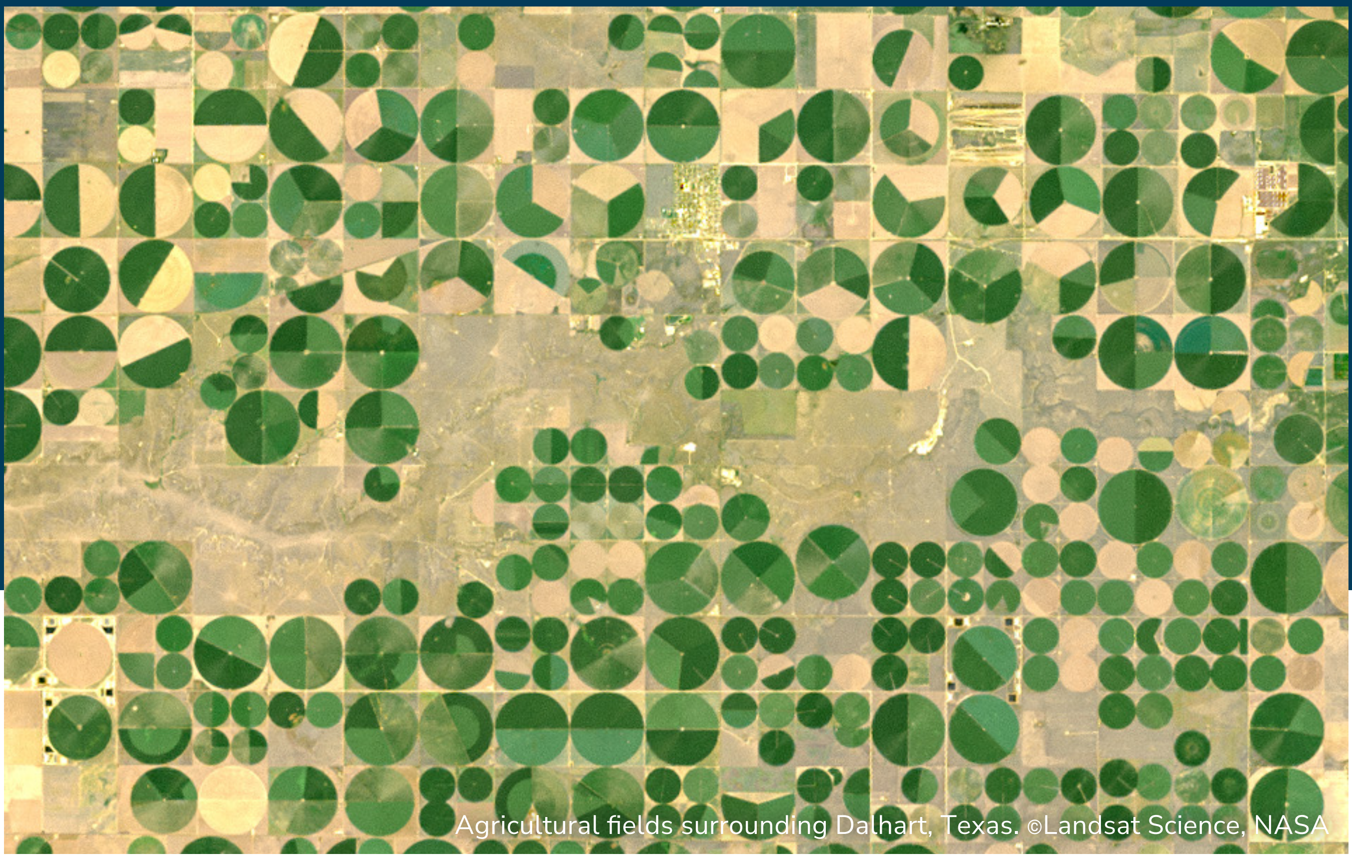
Meadows Report 25-001

Coupled Correlative Allocations for Groundwater Management in Texas:
Overview, Examples, and A Hypothetical Conversion



Agricultural fields surrounding Dalhart, Texas. ©Landsat Science, NASA

Prepared by

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February 2025

THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT
TEXAS STATE UNIVERSITY

MEMBER **THE TEXAS STATE UNIVERSITY SYSTEM**

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Postcard images are courtesy of the personal collection of Dr. Robert E. Mace.

Historical postcard looking upstream Comanche Creek from Government Spring in Fort Stockton, Texas.

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Executive Summary

Effective groundwater management generally requires a management goal and a cap on production. In Texas, groundwater conservation districts are the state's "preferred method for groundwater management." Groundwater conservation districts set management goals (desired future conditions), and the Texas Water Development Board estimates how much groundwater can be produced to achieve those goals (modeled available groundwater). However, few districts issue permits that, if honored, will prevent groundwater production from exceeding the modeled available groundwater. As production increases, groundwater districts can change the desired future to accommodate the additional production; however, this is less managing toward a goal and more avoiding potential regulatory takings lawsuits.

In the same decision where the Texas Supreme Court held that groundwater cannot be taken for public use without adequate compensation, the Court also stated that "one purpose of groundwater regulation is to afford each owner of water in a common subsurface reservoir a fair share." One way to afford each landowner a fair share is to give each of them a correlative right to the groundwater beneath their land.

Correlative rights refer to the legal principle that landowners have a shared right to produce from an underlying aquifer in a manner that does not unfairly diminish the resource or deprive others of their reasonable share. Correlative rights infer proportional sharing, usually by surface acreage. Because of the different ways that districts have employed correlative "rights" in Texas, we refer to correlative allocations. In some cases, correlative allocations are equivalent to correlative rights, but in other cases, it's arguable. Regardless, both correlative rights and correlative allocations distribute the ability to produce groundwater by acreage or some other measure of surface area.

Correlative allocations have a long history in Texas, reaching as far back as 1977. Today, about 60 percent of groundwater conservation districts employ correlative allocations (in some form) in their rules, with a median correlative allocation of 1.5 acre-feet per acre per year.

Groundwater conservation districts have employed correlative allocations in various creative ways to meet their local regulatory needs. Some districts give a correlative allocation with a process to request additional production above that allocation. Some districts have time-based allocations (one allocation before a certain date and another after that date) or do not require historic use permits to adhere to newer allocation rules. Some have different allocations for different uses or exempt certain uses, such as public water supply, from allocation rules. Other districts employ equations to define the correlative allocation as a function of acreage and spacing requirements. One district varies its correlative allocation according to acreage and sand thickness, while another bases it on crop type. One district pays landowners on a per acre basis to not use their correlative allocation for a defined number of years into the future.

Districts use correlative allocations in a variety of hydrogeologic settings, including karst aquifers. For example, the Texas Legislature allocated farmers inside the Edwards Aquifer Authority two acre-feet per acre per year for land historically irrigated with the Edwards Aquifer.

We found two broad categories of correlative allocations in Texas, those decoupled from desired future conditions and those coupled to desired future conditions. If every landowner in a district used their decoupled correlative allocations, it would result in more water (and generally much more water) being produced than the modeled available groundwater amount. Coupled correlative allocations are assigned such that if all landowners (or remaining landowners) produced their groundwater, the modeled available groundwater amount would not be exceeded. Only five districts have coupled correlative allocations for all or some of their aquifers (Brewster County Groundwater Conservation District, Coastal Bend Groundwater Conservation District, Corpus Christi Aquifer Storage and Recovery Conservation District, Guadalupe County Groundwater Conservation District, and Post Oak Savannah Groundwater Conservation District), and each one couples to the desired future condition in different ways.

We also analyzed how permits to produce from the Edwards-Trinity (Plateau) Aquifer in Management Zone 1 in the Middle Pecos Groundwater Conservation District could be converted to correlative allocations. We did this by defining a Leon-Belding Productive Zone, dividing wells and land parcels as either inside or outside the zone, and assessed different ways groundwater use could be allocated by acreage, thus providing a defined cap on groundwater production in the productive zone while honoring existing permitted use. We identified two possible ways to do this. The first would be to assign all parcels the correlative allocation for the second-highest lumped parcel (sum of parcels with the same ownership) and work to reduce use in the highest lumped parcel (which is about four times higher than the second-highest). The second would be to assign each parcel its own correlative allocation under the justification that historic use reflects the ability to sustainably access the aquifer. Although this was a proof-of-concept exercise (and thus, the district would have to undertake a more involved and detailed effort to employ), our analysis shows that it is possible to convert historic and existing permits to a correlative allocation.

A major challenge with using correlative allocations is that it may result in small amounts of water on a per acre basis when the modeled available groundwater is spread across a large geographic area. Sustainable groundwater production would only make this number smaller and more challenging. However, there are several benefits, namely that all landowners over the aquifer would have a defined fair share of groundwater with the choice to use it, lease it, sell it, or conserve it in place for later use or other benefits. Correlative allocations force large producers and exporters to accrue the appropriate number of allocations to provide water for their projects rather than buying the minimum amount of land to produce the maximum amount of water. Furthermore, groundwater export may be more palatable to local landowners if they know that they still have a defined allocation. Once correlative allocations are defined, a water market can develop to meet development or environmental goals. Finally, providing all landowners with a fair share of the water underneath their property probably helps groundwater conservation districts defend their management decisions in court.

Disclaimer: The representation of groundwater conservation district rules in this report reflects the rules as they existed at the time of our conducted research. Rule making is an ongoing process that results in changes due to board elections, new management goals, and changing desires of governing boards. The most recent rules can often be found at the districts' respective websites or by making a request directly with a district.

Historical postcard of Government Spring in Fort Stockton, Texas.

Introduction

Effective groundwater management generally requires a management goal and a cap on production. A management goal is needed because if there is no management goal, then there's nothing to manage toward. A cap is needed because if there is a management goal, achieving the management goal hinges on the ability to manage groundwater production.[1] Finally, regulations that honor the underlying groundwater doctrine and existing laws are needed.

In Texas, groundwater conservation districts are the state's "preferred method for groundwater management" (Texas Water Code §36.0015[b]). Indeed, notwithstanding the limited authority embedded with cities, counties, and state agencies, groundwater conservation districts—where they exist—are the primary regulators for groundwater planning, water-well spacing, and groundwater production in the state.

Although groundwater conservation districts set goals (desired future conditions) for the relevant aquifers within their respective groundwater management areas and the Texas Water Development Board estimates how much groundwater can be produced to achieve those goals (modeled available groundwater), few districts issue permits

1 *These proclamations concern groundwater as a water resource and do not apply to preserving water quality (although water-quality goals and means of controlling undesired activity to achieve those goals are still relevant).*

that, if honored, would prevent groundwater production from exceeding the current modeled available groundwater.[2]

There are many reasons that many groundwater conservation districts do not explicitly manage to their managed available groundwater amounts. One reason is regulatory inertia. The process of defining goals and managing to achieve those goals has existed since 2005 and wasn't fully implemented until as late as 2010 (Mace and Brown 2011). This compares to 60 to 70 years with no requirement to define or achieve a goal.[3] As a consequence, many districts modified their existing permitting approach to the new requirements without changing their rules to actually achieve the desired future condition.

Furthermore, subsequent legislation decoupled permits and actual production (Texas Water Code §36.0001[25]) and required districts to renew operating permits if the permittee is in administrative compliance (Texas Water Code §36.1145). This allowed districts to decouple permitting from the modeled available groundwater amount. If production begins to violate the modeled available groundwater amount on an average basis or is on track to do so, districts can change the desired future condition to allow more production, thus avoiding production restrictions and lawsuits by permitholders. In this case, there is no management goal except to avoid getting sued, which is not a management goal for the aquifer.[4] One district has stated that districts are legally obligated for their management goals to include the volumes of permitted water (DBS&A and others 2022 Appendix T).[5]

Fear of being sued is a legitimate concern since many districts are small governmental bodies with limited budgets. Limited budgets mean that many districts are not able to defend themselves against deep-pocketed challengers. Consequently, districts can be bullied through lawsuits and political intimidation to grant permits.[6]

Another issue influencing district action and inaction is that the Texas Supreme Court held in 2012 that landowners own the groundwater beneath their property and that it cannot be taken for public use without adequate compensation (*Edwards Aquifer Authority v. Day and McDaniel* 2012). As stated by the Court, "Groundwater rights are property rights subject to constitutional protection…". This ruling has given districts pause in establishing groundwater management goals that restrict production since districts can be sued for the taking of private property.

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2 *Some argue that the desired future condition and the resulting modeled available groundwater numbers are merely goals and not caps. However, Texas Water Code (§36.3011[b]) clearly states that districts are subject to enforcement actions, including dissolution, by the Texas Commission on Environmental Quality if they do not adopt a desired future condition, fail to update their groundwater management plan with a desired future condition, fail to update their rules to implement the desired future condition, and fail to enforce rules to achieve the desired future condition.*

3 *This time frame comes from when the Legislature first allowed districts to form in 1949 up to 2010.*

4 *We refer to this as "Rule of Capture with speed bumps."*

5 *We disagree.*

6 *We are not saying that districts are not above reproach; they are not. Districts are required to honor state laws and their rules and regulations, even if those rules and regulations are more permissive than they intended.*

Edwards Aquifer Authority v. Day and McDaniel (2012) involved the Authority denying a permit to produce groundwater due to the landowner not meeting the requirements for historic use.[7] In its dicta[8], the court said that denying a landowner access to the water beneath their property due to non-use was not appropriate and that the landowner was due compensation from the Authority, even though the Authority was correctly implementing its enabling legislation.

One way of not being sued for the taking of groundwater as private property is to not do anything that could be interpreted as taking groundwater as private property, and that can be achieved by never denying nor restricting permits. However, this approach results in, effectively, the Rule of Capture. Under Rule of Capture, those who do not currently use their groundwater rights may not receive the same or any benefits of the water in the future.

In *Edwards Aquifer Authority v. Day*, the Texas Supreme Court stated that

> *... non-use of groundwater conserves the resource...*

and

> *To forfeit a landowner's right to groundwater for non-use would encourage waste.*

The Court invoked the concept of "fair share" in its dicta

> *As with oil and gas, one purpose of groundwater regulation is to afford each owner of water in a common, subsurface reservoir a fair share. Because a reservoir's supply of oil or gas cannot generally be replenished, and because oil and gas production is most commonly used solely as a commodity for sale, land surface area is an important metric in determining an owner's fair share.*

The Court went on to state that groundwater is different from oil and gas and that

> *...regulation that affords an owner a fair share of subsurface water must take into account factors other than surface area.*

The Court further stated that

> *Groundwater regulation must take into account not only historical usage but future needs, including the relative importance of various uses, as well as concerns unrelated to use, such as environmental impacts and subsidence.*

Historic use with no subsequent permitting violates fair share principles because only the earliest users get to use the groundwater beneath their land, leaving non-users with limited exempt uses. The Rule of Capture also violates fair share principles since the resource may be depleted before non-users begin their use. Correlative rights, with additional considerations, may be the best way to provide a fair share to all rightsholders while providing an incentive to conserve and creating a water market to achieve higher economic value (Collins 2015).

7 *The details of this case are more nuanced (and interesting) than this brutal distillation.*

8 *Dicta refers to the words in a court opinion used for comments, suggestions, or observations that are not legally binding but still may be cited in future litigation (LII 2024).*

Groundwater conservation districts are not strangers to correlative rights—many districts have used a correlative approach for maximum allowable production for decades. However, few districts tie their correlative allocations to their desired future conditions. The purpose of this research was to (1) demonstrate how a district could convert to correlative rights from an existing permitting approach, (2) assess the pros and cons of doing so, and (3) discuss how such an approach could work in a karst aquifer.

Correlative Rights

Correlative rights refer to the legal principle that landowners have a shared right to produce from an underlying aquifer in a manner that does not unfairly diminish the resource or deprive others of their reasonable share (Pearson 2012). Because of the "fair" and "reasonable" distribution of groundwater, correlative rights are sometimes considered an application of the Reasonable Use Doctrine. The Reasonable Use Doctrine may or may not allocate rights proportionally, but it disallows the transport of groundwater from the property it is produced from (Water Systems Council 2016). In contrast, the Correlative Rights Doctrine, similar to the Rule of Capture, allows groundwater produced from a property to be transported off that property.

The Correlative Rights Doctrine infers proportional sharing (Dellapenna 2013). In general, if not in most cases, correlative rights are assigned proportionally according to surface area over a producing formation. In the United States, the units of that correlation are usually in acres, probably because most groundwater is generally used for irrigation and irrigators generally measure the volume of water they irrigate with by acre-inches or acre-feet. The Correlative Rights Doctrine is currently in whole or in part used by Arkansas, California, Hawaii, Iowa, Oklahoma, and Tennessee (Water Systems Council 2016).

Correlative Allocations in Texas

Although the Rule of Capture has been the foundation of groundwater case law in Texas, largely for tort reasons, the Legislature empowered groundwater conservation districts to manage the resource, including through the granting of permits that may place limits on well placement and production amounts. Except in a few cases, the Legislature has not specified how districts grant permits, allowing a variety of approaches to be used, including correlative rights. Since it is arguable what a correlative right is (and is not) in groundwater conservation district rules, we hereafter refer to *correlative allocations* unless we are referring to the Correlative Rights Doctrine.

It is unclear exactly when groundwater conservation districts in Texas first employed correlative allocations for groundwater. The state's first groundwater district, the High Plains Underground Water Conservation District No. 1, initially used well spacing after its creation in 1951 to regulate production for minimizing well interference[9] (HPUWCD 1954). In 1976, the district noted that, "The drilling and producing of large capacity water wells on small tracts of land has been a continuing problem within the District"

9 *Well interference refers to water-level declines caused by one well affecting water levels in another well.*

(HPUWCD 1976). In response, the district proposed a rule requiring a certain number of acres for a certain amount of production. However, it does not appear that the proposed rule advanced, at least at that time.

On May 26, 1977, a rule adopted by the Panhandle Groundwater Conservation District went into effect limiting the number of wells that could be drilled and produced on a segment of land (HPUWCD 1977). The number of wells that could be drilled and how they could be pumped were a function of well diameter (which limited maximum pump size which is correlated to maximum production ability) and acreage. If the maximum number of wells were pumped the maximum amount year-round, the maximum amount a landowner could produce was about 10 acre-feet per acre per year.

Based on our interpretation of groundwater conservation district rules, about 60 percent of the 98 districts correlate maximum groundwater production for non-exempt use to surface acreage (Appendix A). Correlative allocations assigned by districts range from 0.04 acre-feet per acre per year in the Corpus Christi Aquifer Storage and Recovery Conservation District to more than 90 acre-feet per acre per year in the Brazos Valley Groundwater Conservation District and the Rusk County Groundwater Conservation District (Appendix A). The median (50th percentile) correlative allocation is 1.5 acre-feet per acre per year with 25 percent of values less than or equal to 0.5 acre-feet per acre per year and 25 percent of values greater than or equal to 3 acre-feet per acre per year (Figure 1). Ten percent of values exceed 8 acre-feet per acre per year (Figure 1).

The Brazos Valley Groundwater Conservation District and the Rusk County Groundwater Conservation District allocate production according to a non-linear equation,

$$\frac{(Q_a S_p)^2 \pi}{43{,}560} = A_c \qquad (1)$$

where Q_a is the average annual production rate in gallons per minute, S_p is the district spacing requirement between wells in units of feet per gallon per minute, and A_c is the total number of contiguous acres required to be assigned to the well site (BVGCD 2023, RCGCD 2023):[10] The Brazos Valley Groundwater Conservation District assigns a district spacing requirement of 2 feet per gallon per minute for wells producing from the Brazos River Alluvium and 2 feet per gallons per minute for all other aquifers (BVGCD 2023). The Rusk County Groundwater Conservation District assigns a district spacing requirement of 0.5 feet per gallon per minute from the perimeter of the property and 1 foot per gallon per minute from permitted and registered wells in the district (RCGCD 2023). We solved this equation for one acre for our analysis.

10 *Since we conducted our original analysis, the Brazos Valley Groundwater Conservation District changed its rules. The equation remains the same, but the average annual production rates and spacing requirements have changed for certain aquifers. For the Brazos Valley Groundwater Conservation District, the average annual production rate is now 1 foot per gallon per minute for wells producing from the Brazos River Alluvium, and the spacing requirement for all other aquifers is now 1 foot per gallon per minute from the perimeter of the property and 2 feet per gallons per minute for from a permitted or registered well (BVGCD 2024).*

Our one-acre calculation represents a maximum correlative amount available for permitting and use because the relationship allows less production on a per acre basis with greater amounts of contiguous acreage (Figure 2). In this case, the correlative allocation is not only a function of the acreage—it is a function of how much contiguous acreage there is. While it might not make initial sense to lower the volume per acre that can be pumped with greater acreage, this approach requires more acreage for larger capacity wells. For example, 90 acre-feet per acre per year amounts to a well producing about 56 gallons per minute; a large-capacity well of 1,000 gallons per minute and a spacing requirement of 0.5 feet per gallon per minute would require a minimum of 18 acres to be permitted.

Several districts relate correlative allocations to other factors in addition to surface acreage. The Guadalupe County Groundwater Conservation District ties their correlative allocation to net sand thickness (GCGCD 2023) while the Hemphill County Groundwater Conservation District considers which crop is irrigated (HCGCD 2023). Correlative allocations for the Guadalupe County Groundwater Conservation District range from 0.000006 to 0.81 acre-feet per acre with a median of 0.17 and an average of 0.20 acre-feet per acre (Figure 3).

Other districts adjust the correlative allocation approach to meet their local needs:

- The McMullen Groundwater Conservation District and the Irion County Water Conservation District have correlative allocations but allow for more production (MGCD 2012, ICWCD 2023).
- The Medina County Groundwater Conservation District has one correlative allocation for permits issued before a certain date and a different one issued after a certain date (MCGCD 2017), the Victoria County Groundwater Conservation District has different correlative allocations for historic use and newer permits (VCGCD 2024), and the Post Oak Savannah Groundwater Conservation District's correlative allocations do not apply to historic use permits (POSGCD 2023).
- The Middle Trinity Groundwater Conservation District has a larger correlative allocation for certain retail public water utilities (MTGCD 2023) while correlative allocations in the Real-Edwards Conservation and Reclamation District do not apply to public water supply wells (R-ECRD 2023).
- The Pecan Valley Groundwater Conservation District bases its correlative allocation on well depth and water quality (PVGCD 2023). In addition to a correlative allocation, the Refugio Groundwater Conservation District regulates the maximum pumping rate of wells based on acreage (RGCD 2024).

Many districts use a combination of approaches when managing their resources (such as preserving historic use while using correlative allocations for new permits) and reserve the authority to reduce allocations when such use conflicts with management goals.

When evaluating districts' rules, we noticed that the correlative allocations we documented fell into two broad categories: those tied directly to modeled available groundwater amounts and those that are not. We refer to correlative allocations tied directly to modeled available groundwater numbers as "coupled correlative allocations" since those allocations are directly coupled to the management goal. We refer to correlative allocations not tied directly to modeled available groundwater numbers as "decoupled correlative allocations."

Although not a correlative allocation *per se*, minimum tract size requirements for certain exempt uses[11] may call for a minimum amount of land before allowing a well to be drilled. Exempt uses in Texas include providing groundwater for domestic purposes or providing water for livestock or poultry as long as the use is equal to or less than 25,000 gallons per day and is located on a piece of land larger than 10 acres (Texas Water Code §36.117[b][1]).[12] Districts can be more permissive in their rules or, if their enabling legislation and subsequent amendments allow it, more restrictive. We did not consider these minimum acreage requirements as correlative allocations in our analysis, but we reviewed district rules for minimum tract size requirement due the association of production with land area. In all, 41 of the 98 districts (42 percent) employ minimum acreage requirements ranging from 1.7 to 10 acres with 37 of the districts using the 10 acres in the Water Code (Appendix B).

A total of 71 districts uses 25,000 gallons per day at the upper limit for these exempt uses with 2 districts having a lower number (10,000 gallons per day), 6 specifying higher numbers (as high as 100,000 gallons per day), and 19 with no production limit (Appendix B).

A use of 25,000 gallons per day, a number that appears to source from *Houston & Texas Central Railroad Co. v. East* (1904) case where the railroad was pumping 25,000 gallons per day, equates to a well pumping 17.4 gallons per minute or 28 acre-feet per year. For a minimum acreage of 10 acres, that amounts to 2.8 acre-feet per acre per year. However, note that the exemption is for a well, not total production, so theoretically there is no limit on how much water can be pumped for exempt use except for, perhaps, practical limits. For example, a typical Texan uses about 75 gallons per person per day on average (WCAC 2022) and a typical Texan household includes 2.76 people (U.S. Census Bureau 2023). That means that a typical Texan household uses about 207 gallons per day or 0.23 acre-feet per acre per year. With a typical city lot in Texas at 0.22 acres (Pacheco 2022), a typical urbanized acre would require about 1 acre-foot per acre per year of water.

We made these calculations to note that (1) exempt use, as specified in the statute can be quite large compared to practical, non-exempt use (28 times larger for domestic use) on an acre-by-acre basis, and (2) exempt use can be a large component of overall production in less-productive aquifers, such as the Trinity Aquifer in the Hill Country.

11 Exempt uses are uses exempt from a district's production and spacing requirements.

12 There are other exemptions, but these are the ones that have this acreage requirement. A district's enabling legislation (if created by the legislature) or subsequent amendments to that enabling legislation may modify the use amount and the minimum acreage. Outside of district-specific legislation, districts are not able to be more restrictive than the Water Code, but they can choose to be less restrictive.

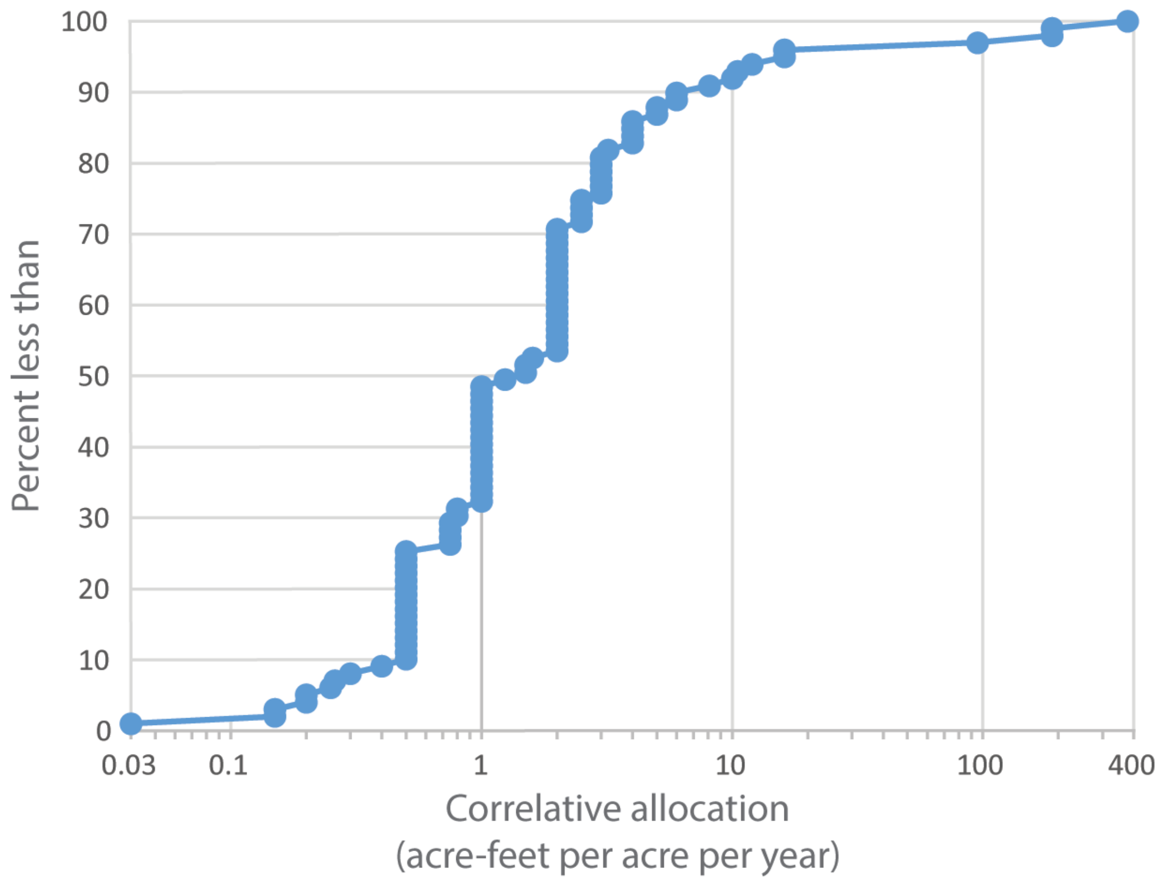

Figure 1. A cumulative distribution function of correlative allocations used by various groundwater conservation districts.

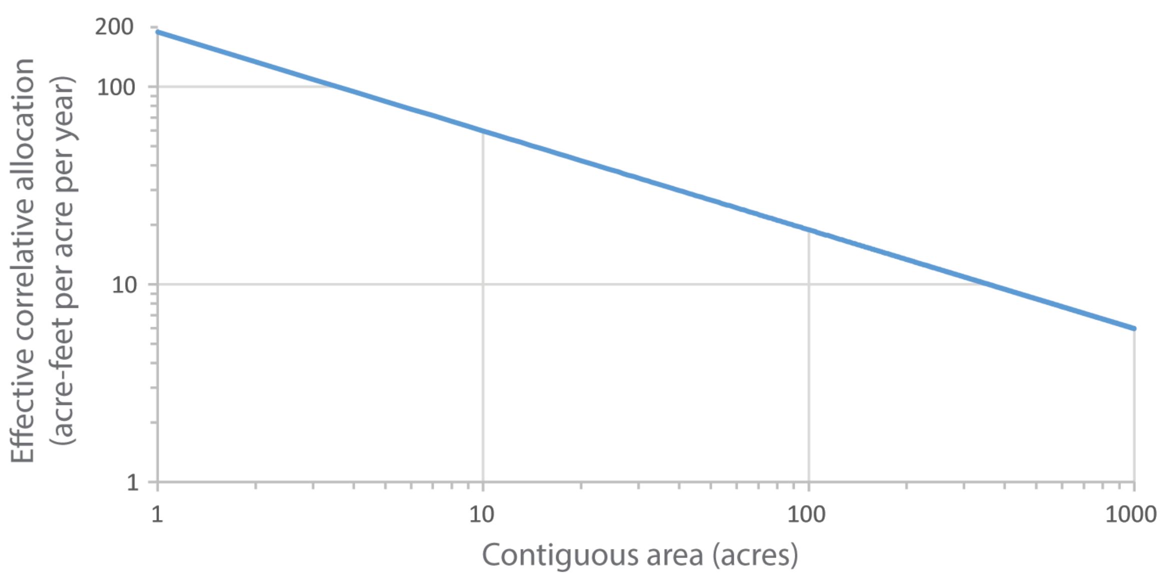

Figure 2. Effective correlative allocation for different amounts of contiguous area using a "district spacing requirement between wells" value of 1 gallon per minute per foot, an approach used by the Brazos Valley Groundwater Conservation District and the Rusk County Groundwater Conservation District. Note that the x-axis and y-axis are logarithmic scales. Line is based on Equation 1 in the text.

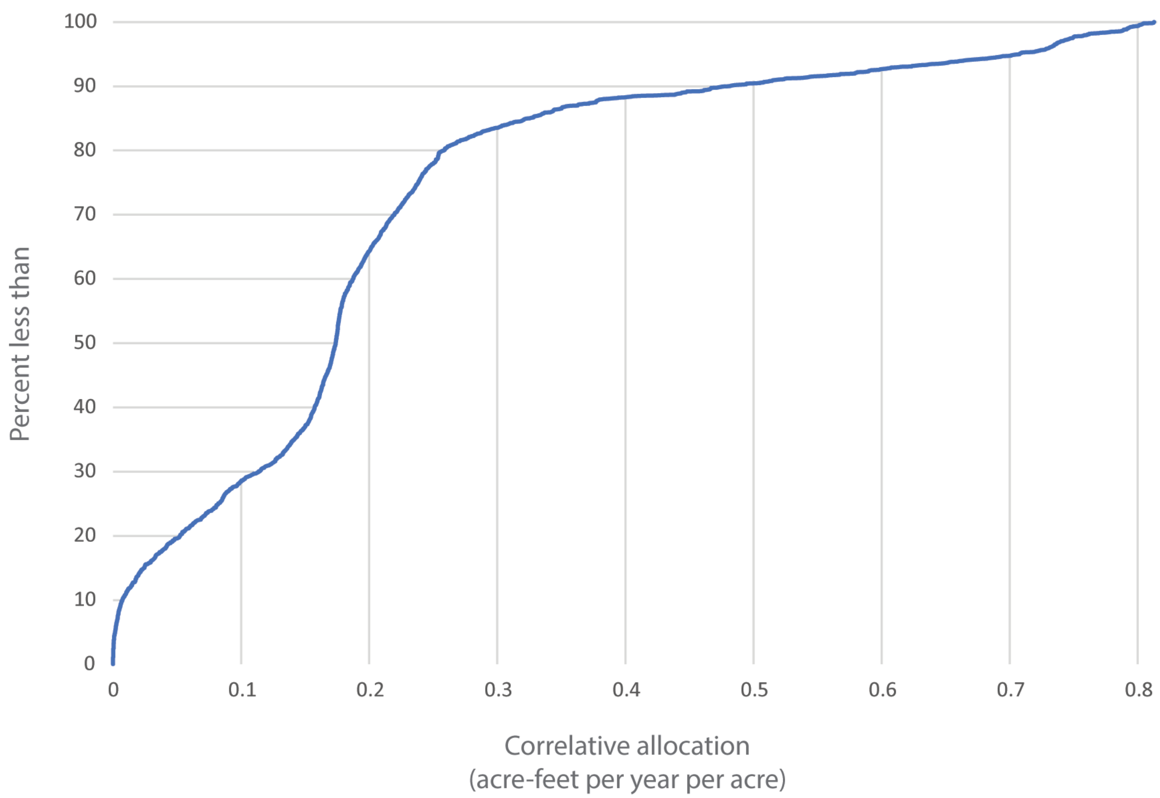

Figure 3. Distribution of correlative allocations in the Guadalupe County Groundwater District.

Decoupled Correlative Allocations

Many groundwater conservation districts did not have explicit, aquifer-based management goals until the passage of House Bill 1763 in 2015. House Bill 1763 required districts in groundwater management areas to jointly define desired future conditions for their aquifers. Once defined, the Texas Water Development Board then provides modeled available groundwater numbers, which are estimates of how much can be pumped without violating the desired future conditions. Groundwater conservation districts are required to amend and enforce their rules to achieve the desired future condition, and regional water planning groups are required to use the modeled availability groundwater numbers for their planning purposes.

Many districts still retain their correlative allocation approach, but many of those allocations are decoupled from the desired future conditions. For example, the Bandera County River Authority and Groundwater District sets a production limit of 1 acre-foot per acre per year (BCRAGD 2022).[13] The desired future conditions resulted in a total managed available groundwater amount of 9,293 acre-feet per year for the district (Dowlearn 2022a). With an area of 791.0 square miles (USCB 2024), a correlative allocation based on the managed available groundwater amount results in 0.018 acre-feet per acre per year.

13 *The district's rules allow for a lower production limit "in areas where water availability studies indicate insufficient water is available for permitting" (BCRAGD 2022). District rules use number of connections instead of acreage for public water suppliers.*

If every landowner in the district produced their correlative allocation of 1 acre-foot per acre per year, this would result in an annual production of 506,240 acre-feet, about 55 times more production than the modeled available groundwater amount. If their correlative allocation was 0.018 acre-feet per acre per year (in other words, based on or intending to limit production to the modeled available groundwater amount), it would be coupled with the desired future condition. Since their correlative allocation has nothing to do with the modeled available groundwater amount, it is decoupled. To be fair, many (but not all) districts have adopted rules to limit groundwater production once that production begins to violate desired future conditions.

The situation where a decoupled correlative allocation results in substantially more groundwater production than the management goal allows is common among districts. On one hand, a decoupled correlative allocation allows more intense use of groundwater by some landowners before all the modeled available groundwater is produced. On the other hand, once all the modeled available groundwater is produced, the incentive is for a district to loosen the desired future condition to allow more groundwater production, something that might happen repeatedly to avoid being sued for a regulatory taking. A district could say that once all the modeled available groundwater is produced, they will not issue any more permits; however, that could put them in direct conflict with the Texas Supreme Court, which stated that "a landowner cannot be deprived of all beneficial use of the groundwater below his property merely because he did not use it during an historical period and supply is limited."

Of the 59 districts that use correlative allocations in their permitting, correlative allocations are decoupled from the desired future condition in 54 of them.

Coupled Correlative Allocations

A coupled correlative allocation is directly coupled to the management goal. In Texas, the management goal is the desired future condition of which the modeled available groundwater amount is the best estimate of how much can be produced without violating that condition. A coupled correlative allocation provides a fair share of the modeled available groundwater to every landowner because every landowner has a defined allocation based on their acreage and their allocation of modeled available groundwater. Because landowners have these defined allocations, they can use it, not use it, sell it, or lease it as they see fit. Because there is a cap on production, there can be a market for groundwater where rights are bought, sold, or leased. Users with greater demands for groundwater can accrue enough water allocations to meet their needs assuming that there are willing sellers or leasers. Conservationists can "buy and dry" (purchase an allocation and not use it) to achieve environmental or other goals. With coupled correlative allocations, groundwater districts can pursue real management goals rather than goals they must change to avoid getting sued. Aquifers without real management goals place all users in jeopardy. Of the 59 districts that use correlative allocations in their permitting, correlative allocations are coupled to the desired future condition in 5 of them.

Examples of Coupled (or Near-Coupled) Correlative Allocations in Texas

Several groundwater conservation districts have employed correlative management approaches to manage their aquifers. In this section, we present information on these districts (aquifers, desired future conditions, modeled available groundwater amounts) and discuss how their rules address correlative allocations. These approaches (listed by district in alphabetical order) are applied to a variety of hydrogeologic settings, including sandstones, fractured volcanics, and limestones.

Brewster County Groundwater Conservation District

Created in 2001, the Brewster County Groundwater Conservation District is coterminous with Brewster County and overlies the Captain Reef Complex, Edwards-Trinity (Plateau), Igneous, and Marathon aquifers. The desired future condition for 2060 set by the districts in Groundwater Management Area 4 for these aquifers in Brewster County are (1) 0 feet of drawdown in the Capitan Reef Complex, (2) 3 feet of drawdown in the Edwards-Trinity (Plateau), (3) 10 feet of drawdown in the Igneous, and (4) 0 feet of drawdown in the Marathon (Hutchison 2021). These desired future conditions resulted in modeled available groundwater amounts for Brewster County of (1) 583 acre-feet per year in the Capitan Reef Complex, (2) 1,394 acre-feet per year in the Edwards-Trinity (Plateau), (3) 2,587 acre-feet per year in the Igneous, and (4) 7,327 acre-feet per year in the Marathon (Boghici and Bradley 2022).

The district's rules provide an equation that defines a correlative allocation directly coupled to the modeled available groundwater amount (BCGCD 2023):

$$WAF_a = \frac{(MAG_a - EP_a - FP_a)}{QL_a}$$

where WAF_a is the water allocation factor in acre-feet per acre per year for aquifer a, MAG_a is the modeled available groundwater in acre-feet per year for aquifer a, EP_a is average annual existing exempt and non-exempt use production in acre-feet per year for aquifer *a*, FP_a is the future production of exempt and non-exempt use in acre-feet per year for aquifer *a*, and QL_a is the acreage of qualifying lands for aquifer *a*:

Essentially, the correlative allocation is based on the modeled available groundwater minus current use minus the sum of projected exempt use and further use of existing permits divided by the area overlying the productive area of the aquifer and not already permitted.

Coastal Bend Groundwater Conservation District

Created in 2001, the Coastal Bend Groundwater Conservation District is coterminous with Wharton County and overlies the Gulf Coast Aquifer. The desired future condition set by the districts in Groundwater Management Area 15 for the Gulf Coast Aquifer in

Wharton County was 15 feet of drawdown in the Chicot and Evangeline sub-aquifers of the Gulf Coast Aquifer (GMA 15 2021). This desired future condition resulted in a modeled available groundwater amount for Wharton County of 181,446 acre-feet per year (Dowlearn 2022b).

The district's rules use the modeled available groundwater amount to set a "minimum MAG-derived amount" that authorized production will never fall below (CBGCD 2023). The district defines the minimum MAG-derived amount as "a groundwater withdrawal amount per acre equal to the Modeled Available Groundwater divided by the total acreage in the District." In the meantime, groundwater users can produce more than minimum MAG-derived amounts, subject to other rules of the district; however, once everyone starts producing their groundwater, the amount each landowner can use is a correlative allocation based on the desired future condition.

Corpus Christi Aquifer Storage and Recovery Conservation District

Created in 2005 (and shaped like a fir tree car freshener), the Corpus Christi Aquifer Storage and Recovery Conservation District includes parts of Aransas, Kleberg, and Nueces counties and overlies the Gulf Coast Aquifer, including brackish waters in the aquifer and in equivalent sediments. The districts in Groundwater Management Area 16, including the Corpus Christi Aquifer Storage and Recovery Conservation District, did not specify a desired future condition for district (Young 2022). However, in its rules, the district defines a correlative allocation based on fresh and brackish groundwater flow into the Gulf Coast Aquifer in the district (CCASRCD 2016). This amounts to 620,000 acre-feet per year for an area of about 15,000,000 acres resulting in a correlative allocation of 0.04 acre-feet per acre per year.

Although the Corpus Christi Aquifer Storage and Recovery Conservation District doesn't have a desired future condition and therefore no modeled available groundwater amount, they identified a management goal in the amount they want to be produced and allocated it according to acreage.

Guadalupe County Groundwater Conservation District

Created in 1999, the Guadalupe County Groundwater Conservation District is located in the south-eastern part of Guadalupe County, where the Carrizo-Wilcox Aquifer exists. In addition to the Carrizo-Wilcox, there is a small area of the Queen City Aquifer in the most south-eastern part of the district. The desired future condition set by the districts in Groundwater Management Area 13 for the Carrizo-Wilcox Aquifer in the management area was (1) 75 percent of the saturated thickness in the outcrop at the end of 2012 remains by the end of 2080 in the management area and (2) an average drawdown of 48 feet (+/- 5 feet) calculated from the end of 2012 conditions through the year 2080 for the management area (GMA 13 2022). This desired future condition resulted in a modeled available groundwater amount for the Carrizo-Wilcox Aquifer in Guadalupe County of 55,637 acre-feet per year in 2020 decreasing to 41,659 acre-feet per year by 2080 (Wade 2022).

For the Carrizo sub-aquifer, the district distributes the modeled available groundwater amount spatially but, in addition to acreage overlying the aquifer, also factors in sand thickness (Blumberg and Collins 2016). In this case, if two properties have the same acreage but Property A has twice as much sand as Property B, Property A will receive an allocation of groundwater twice that of Property B. In this case, groundwater is allocated according to geologic information in addition to acreage. The district updates the allocations as their geologic information is refined and posts allocations to its web page (https://gcgcd.org/index.html). It is unusual to include a hydrogeologic aspect in a correlative groundwater right[14], but if the data is available, this may be an option for districts.

Lost Pines Groundwater Conservation District

Created in 1999, the Lost Pines Groundwater Conservation District includes Bastrop and Lee counties and is underlain by the Carrizo-Wilcox, Queen City, Sparta, Trinity, and Yegua-Jackson aquifers. The desired future conditions set by the districts in Groundwater Management Area 12 for Bastrop and Lee counties between 2011 and 2070 were (1) 28 feet of average drawdown in the Queen City Aquifer, (2) 22 feet of average drawdown in the Sparta Aquifer, (3) 134 feet of average drawdown in the Carrizo Aquifer, (4) 132 feet of average drawdown in the Calvert Bluff, (5) 138 feet of average drawdown in the Hooper, and (6) 240 feet of average drawdown in the Simsboro (DBS&A and others 2022). The Carrizo, Calvert Bluff, Hooper, and Simsboro are sub-aquifers of the Carrizo-Wilcox Aquifer in this area.

These desired future conditions resulted in modeled available groundwater amounts of (1) 1,109 acre-feet per year in 2020 increasing to 1,771 acre-feet per year in 2070 in the Queen City, (2) 1,042 acre-feet per year in 2020 increasing to 2,723 acre-feet per year in 2070 in the Sparta, (3) 4,716 acre-feet per year in 2020 increasing to 12,980 acre-feet per year in 2070 in the Carrizo, (4) 2,155 acre-feet per year in 2020 increasing to 5,563 acre-feet per year in 2070 in the Calvert Bluff, (5) 1,691 acre-feet per year in 2020 increasing to 3,278 acre-feet per year in 2070 in the Hooper, and (6) 20,364 acre-feet per year in 2020 increasing to 79,945 acre-feet per year in 2070 in the Simsboro (Shi and Harding 2022).

Hutchison (2023) investigated how the district could use a correlative management approach to allocate permits. He contrasted what a correlative allocation for the Simsboro Aquifer would be (0.09 acre-feet per acre per year) with the equivalent correlative allocation for a permit issued to the Lower Colorado River Authority (1.6 acre-feet per acre per year). Ultimately, Hutchison (2023) recommended, and the district adopted, "short-term" correlative allocations based on the 1.6 acre-feet per acre per year given to the Lower Colorado River Authority. "Short term" meant to convey that these numbers may have to change to meet long-term management goals. That means these short-term correlative allocations are not coupled to the desired future condition. As Hutchison (2023) notes, acreage would have to be "removed" or water "added" to achieve the desired future condition at the current rate of 1.6 acre-feet per acre per year.

14 Correlative Rights Plus©

Post Oak Savannah Groundwater Conservation District

Created in 2001, the Post Oak Savannah Groundwater Conservation District includes Burleson and Milam counties and overlies the Brazos River Alluvium, Carrizo-Wilcox, Queen City, Sparta, Trinity, and Yegua-Jackson aquifers. The desired future conditions set by the districts in Groundwater Management Area 12 for the relevant aquifers in the district for 2011 through 2070 include 30 feet of drawdown for the Queen City, 32 feet for the Sparta, 146 feet for the Carrizo, 156 feet for the Calvert Bluff, 178 feet for the Hooper, and 278 feet for the Simsboro (the latter four being sub-aquifers of the Carrizo-Wilcox Aquifer) (DBS&A and others 2022).

These desired future conditions resulted in modeled available groundwater amounts of (1) 63,634 acre-feet per year in 2020 increasing to 63,564 acre-feet per year in 2070 in the Brazos River Alluvium, (2) 513 acre-feet per year in 2020 increasing to 7,839 acre-feet per year in 2070 in the Queen City, (3) 1,237 acre-feet per year in 2020 increasing to 4,105 acre-feet per year in 2070 in the Sparta, (4) 1,094 acre-feet per year in 2020 increasing to 6,058 acre-feet per year in 2070 in the Yegua-Jackson, (5) 11,209 acre-feet per year in 2020 increasing to 18,206 acre-feet per year in 2070 in the Carrizo, (6) 2,179 acre-feet per year in 2020 increasing to 4,706 acre-feet per year in 2070 in the Calvert Bluff, (7) 1,806 acre-feet per year in 2020 increasing to 3,126 acre-feet per year in 2070 in the Hooper, and (8) 29,953 acre-feet per year in 2020 increasing to 79,422 acre-feet per year in 2070 in the Simsboro (Shi and Harding 2022).

As mentioned earlier, the district has a maximum allowable permitted production (currently 2 acre-feet per acre per year) assigned per acre (POSGCD 2023). The district's rules allow for the maximum allowable permitted production to be lowered within management zones based on three threshold levels tied to the desired future condition and modeled available groundwater. If every landowner in the district chose to produce the maximum amount of groundwater, the end result would be a correlative allocation coupled with the desired future condition. With this approach, the district allows landowners and lessees to produce much more than the coupled correlative allocation until others begin enjoying their right to access groundwater, in which case the maximum allowable permitted production would be lowered (aka, "the haircut").

The Post Oak Savannah Groundwater Conservation District also rewards non-users in a correlative manner through its Aquifer Conservancy Program where landowners are compensated for not producing groundwater (POSGCD 2024a, b). The district offers landowners several compensation options for conserving groundwater over different lengths of time, including (1) $5 per acre for a 5-year commitment, (2) $8 per acre for a 10-year commitment, (3) $10 per acre for a 15-year commitment, (4) $15 per acre for a 30-year commitment, and (5) $25 per acre for a 50-year commitment (POSGCD 2024b). In addition to benefiting non-users and helping the district meet management goals, the program also benefits existing producers, allowing them to produce at a rate greater than the coupled correlative allocation.

Some Challenges and Opportunities with Coupled Correlative Allocations

There are several challenges in using correlative allocations. One of those challenges is that achieving long-term management goals with coupled correlative allocations may only authorize relatively small amounts of water per unit area when compared to decoupled allocations (see examples above by us and Hutchison [2023]). Another challenge is that if the long-term management goal is sustainable production, which is not the case for most of the aquifers in Texas (Mace 2021), then coupled correlative allocations would be even lower. Yet another challenge is changing an existing management approach to a correlative allocations approach. As the examples above show, this is certainly possible, but changing a management approach may be politically and legally easier for some districts than others.

Several hydrogeologists and groundwater districts have insisted that correlative allocations are not possible in a karst aquifer (aquifers generally made of limestone [carbonates] with caves and conduits) (various personal communications). However, as shown above, many districts have already employed correlative allocations in karst and carbonate aquifers. Not discussed above is the Edwards Aquifer Authority, where the Legislature assigned agricultural rights at 2 acre-feet per acre per year (EAA 2021). So, not only is it possible to allocate groundwater in karst aquifers—groundwater regulating bodies have done it.

The concern about karst may relate to one property having a major conduit, and thus greater ability to produce, while another one doesn't. But why does a property without a major conduit deserve a right greater than the property with a conduit? The Texas Supreme Court stated that landowners own the water beneath their property. While permeability facilitates the production of groundwater, it is not the water itself. In addition, a conduit often acts as an extended (often horizontal) well, so why does a property with a greater ability to drain its neighbors deserve a right greater than the neighbor's property? This is not to argue against using reliable geologic information in assigning correlative rights (for example, the Guadalupe County Groundwater Conservation District's consideration of sand thickness), but to simply note that it is not required.

Although there are challenges to employing correlative allocations, there are also a number of benefits. One benefit is granting all landowners above the aquifer a defined right in the groundwater beneath their land. Once defined, a landowner can choose to use, lease, sell, or conserve it in place for later use or other benefits.[15] Correlative allocations force large producers and exporters to accrue the appropriate amount of allocations to provide water for their projects rather than buying the minimum amount of land to produce the maximum amount of water. Groundwater export may be more palatable to local landowners if they know they still have a defined allocation.

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15 *Conserving in place only provides a benefit to the landowner if an aquifer is being managed sustainably. If an aquifer is not being managed sustainably, then the correlative allocation associated with a property may be produced by neighbors not conserving their water in place. In other words, the Tragedy of the Commons still applies, albeit managed.*

Once correlative allocations are defined, a water market can develop. A market facilitates larger projects, if they can accrue the acreage, but also allows water conservationists to “buy and dry” rights for environmental purposes. Other producers may buy or lease water allocations and not use them to benefit their own production or minimize impacts from their own production. As discussed earlier, the Post Oak Savannah Groundwater Conservation District rewards non-users through its Aquifer Conservancy Program, where landowners are compensated for not producing their correlative allocation (POSGCD 2024).

Correlative allocations may allow districts to better defend their management actions, such as production curtailment, in court because, with correlative allocations, every landowner has their own fair share of the aquifer. Challengers would have to convince the court why all landowners are equal, but some are more equal than others.[16] Furthermore, investment-backed expectations, an important part of regulatory takings lawsuits (Washburn 1996, Eagle 2000, Stein 2002), may not be (and are probably not) forever, perhaps allowing for a measured transfer from one regulatory approach to another if existing property rights are affected by a change.

16 *With vague apologies to Orwell (1945).*

Converting to Coupled Correlative Allocations: A Hypothetical Example in Pecos County

Management Zone 1 in the Middle Pecos Groundwater Conservation District offers a unique opportunity to investigate how correlative allocations could be employed in a sustainably managed karst aquifer. There are several unique aspects to Management Zone 1. One is that the aquifer self-optimized to sustainable production outside of active management due to the relatively quick feedback the aquifer gives to users when pumped above sustainable levels (Mace 2022). This means that the aquifer is "fully or near-fully produced," although a recent water budget analysis suggests that permits, if fully pumped, may exceed the maximum sustainable yield of the system (Mace and others 2020). Another unique aspect is that there is interest in developing a market for groundwater rights to return year-round flows at Comanche Springs (Mace and others 2020, Texas Water Trade 2024).

Finally, there is (or should be) a strong incentive to firm up water rights in the aquifer. At present, there is no cap on groundwater permitting in Management Zone 1, meaning that the district can still issue permits in the zone. Furthermore, existing users are concerned that groundwater export could affect the long-term reliability of the system (Mace and others 2020). A cap on production that honors current water permits and landowners may go a long way toward alleviating those concerns. The potential exporter, the West Texas Water Partnership of Midland, San Angelo, and Abilene, is particularly vulnerable to further permitting since export permits are the first to be proportionally reduced under the district's rules. A cap would protect the resource from additional permits in an already over-permitted aquifer. Furthermore, any efforts by parties seeking to more reliably return springflow to Comanche Springs would increase the reliability of the West Texas Water Partnership's export supply as well as permits held by others.

The purpose of this analysis was to assess the technical challenges in changing from the current regulatory approach to a correlative allocation one and offer options for the district to consider.[17] Although this analysis is focused on a karst aquifer with several unique attributes, any district considering a complete or partial conversion to correlative rights will likely find it useful.

Study Area

We focused our proof of concept on Management Zone 1 in Pecos County, Texas (Figure 4). Physiographically, Management Zone 1 is part of the High Plains due to a thin veneer of sediments from the erosion of the Rocky Mountains (Wermund 1996), but geologically—and hydrogeologically—the Edwards Plateau is a more defining feature. The average annual temperature is about 60° Fahrenheit, the average annual rainfall is about 15 inches, and the average annual gross lake evaporation is about 75 inches (TWDB 2012). Land-surface elevation ranges from about 3,250 feet above

17 The district provided information to us for this study but did not request or fund the study.

sea level just south of Belding to 2,930 on the northern end of Rooney Park in Fort Stockton.

The Middle Pecos Groundwater Conservation District regulates groundwater use in Pecos County and employs management zones to regulate unique parts of the Edwards-Trinity (Plateau) Aquifer. The district defined Management Zone 1 to encompass (1) the Leon-Belding Irrigation Area located between Leon Springs to the north (dry since the 1950s) and Belding to the south and (2) Comanche Springs (currently seasonal) on the east side of Fort Stockton (Figure 4). The Leon-Belding Irrigation Area represents an unusually productive part of the Edwards-Trinity (Plateau) Aquifer in this area due to localized faulting that has dropped geologic formations in the area by as much as 500 feet within the Belding-Coyanosa Trough, a trough created through the dissolution of salts in deeper sediments (Clark and others 2013).

Faulting in the Belding-Coyanosa Trough has allowed brackish groundwater from deeper sediments to flow into the limestone of the Edwards as well as fresher flows from recharge areas in the Glass Mountains to the south (Mace and others 2020). These flows, in combination with fault-associated fracturing, have partially dissolved the Edwards rocks, creating a pocket of highly-productive wells. Somewhere between the Leon-Belding Irrigation Area and Comanche Springs, there is a flow system connecting the two areas (Mace and others 2020).

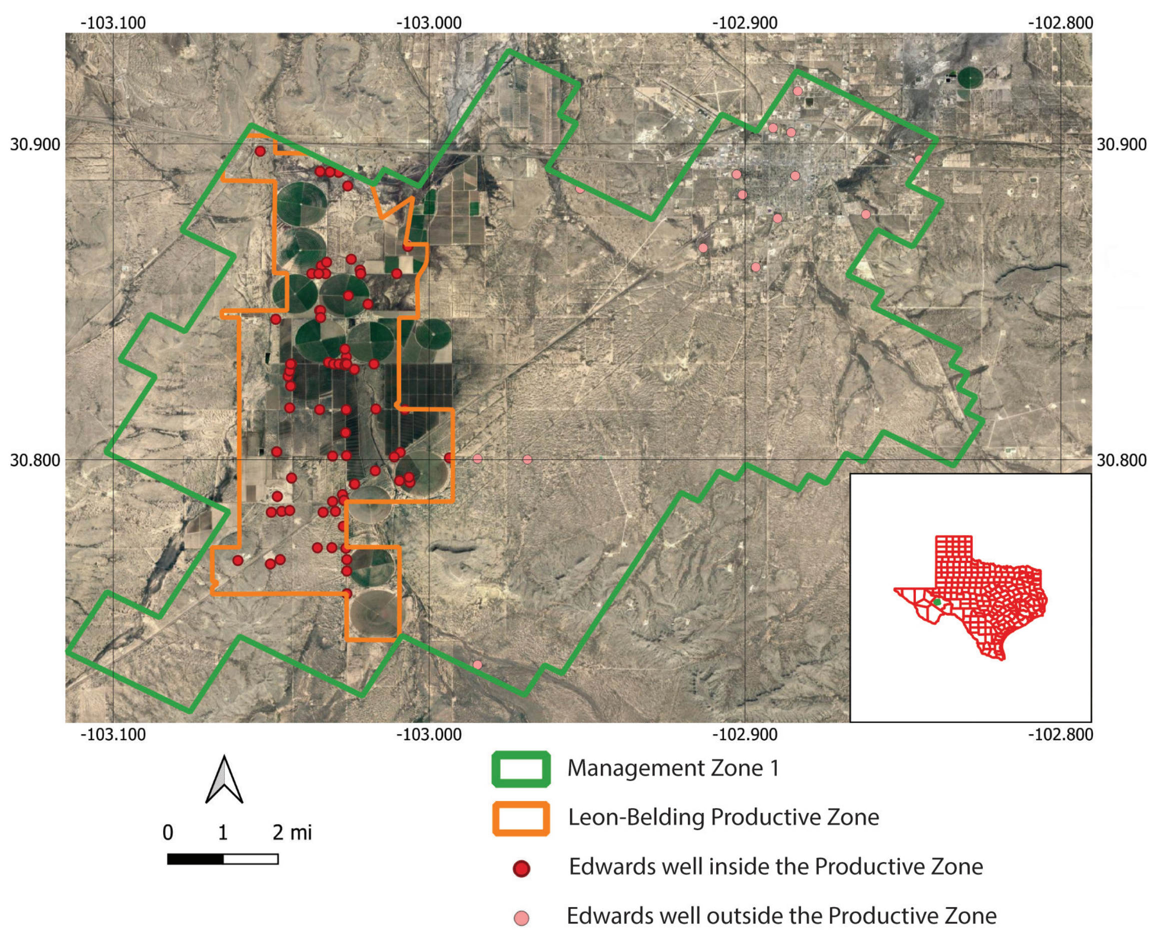

Figure 4. Wells in Management Zone 1 and the Leon-Belding productive zone.

Current Regulatory Approach

The district regulates groundwater use in the entire county but has employed management zones that have their own rules and regulations. The Leon-Belding-Comanche Springs area has its own management zone due to its unique hydrogeology. The district currently has a mix of approaches for regulating groundwater use in Management Zone 1. This includes historic use permits (what they term historic and existing use permits where existing means being used at the time the permits were issued or in the past), production permits (permits issued after the issuance of historic use permits), and export permits (Mace and others 2020). These permits are treated in a sort of bulked prior-appropriation approach where, when aquifer levels are below certain thresholds, export permits are first reduced proportionally to zero before production permits are reduced proportionally (Mace and others 2020). Once production permits are reduced to zero, historic use permits are reduced proportionally (Mace and others 2020). New permits can be requested and issued in the management zone, so there is not a cap on production.

Approach

Our approach involved (1) acquiring a database of permitted groundwater use in Management Zone 1, (2) acquiring a database of parcel ownership for parcels in Management Zone 1, (3) using the databases to harmonize parcel ownership and permit holders, and (4) calculating hypothetical correlative allocations in several different ways.

We acquired the database of permitted groundwater use in Management Zone 1 from the Middle Pecos Groundwater Conservation District for permits as of July 2023. The variables in the database we considered in our analysis included (1) permit holder names, (2) areas of parcels within Management Zone 1, (3) aquifers the wells were completed in, and (4) permitted production for each well.

We acquired geographic information system files for parcels and a database of parcel ownership for parcels in Management Zone 1 through the Pecos County Tax Appraisal Office's web page (PCAD 2023). Information we used from the Appraisal Office's database included (1) parcel ownership and (2) parcel area. We used QGIS, an open-source geographic information platform (QGIS.org 2024), to process geographic information. Most parcels in the productive zone had permitted wells (Figure 5).

We used the databases to harmonize parcel ownership and permit holders and identify the owners of parcels in what we defined as the Leon-Belding Productive Zone in Management Zone 1. We defined the productive zone through a combination of permits for productive wells and locations in the Leon-Belding irrigation area.

We confronted several challenges in harmonizing the data. Some of these challenges included differences between parcel boundaries and satellite imagery and differences between well locations and satellite imagery. Other challenges related to parcel ownership included non-identified ownership (no entry) and parcel ownership unmatched with a well permit holder name. We attempted to remedy these issues with site visits to the groundwater conservation district and the appraisal office; however, it became clear that this would be a time-consuming, on-site effort to get completely correct, which was beyond the scope of our study. Therefore, we did the best we could with the information we had, deferring in most cases to information from the groundwater conservation district. This meant that our analysis was interpretive rather than definitive. In other words, if the district decided to adopt a correlative allocation approach, they would need to conduct a much more definitive analysis for regulatory purposes. Accordingly, we anonymized ownership and permit numbers in our analysis and results.

The raw data included two tables: a well permit table and a parcel table. The pre-processing involved two steps. First, in QGIS, we calculated all the parcel areas within Management Zone 1 in units of acres and appended the new column to the parcel table. Second, we joined the well permit table with the parcel table so that the well-permit table also contained the "parcel area" column. We then exported that table from QGIS and loaded it into Matlab for post-processing. During the first step of the post-processing, we selected the wells that are pumped from the Edwards-Trinity (Plateau) Aquifer and then manually corrected the parcel owner information based on the parcel's spatial distribution shown in GIS shapefiles, field observations, satellite imagery of well locations relative to parcels, and well permit holder data, so that parcel ownership matched the well permit holder name.

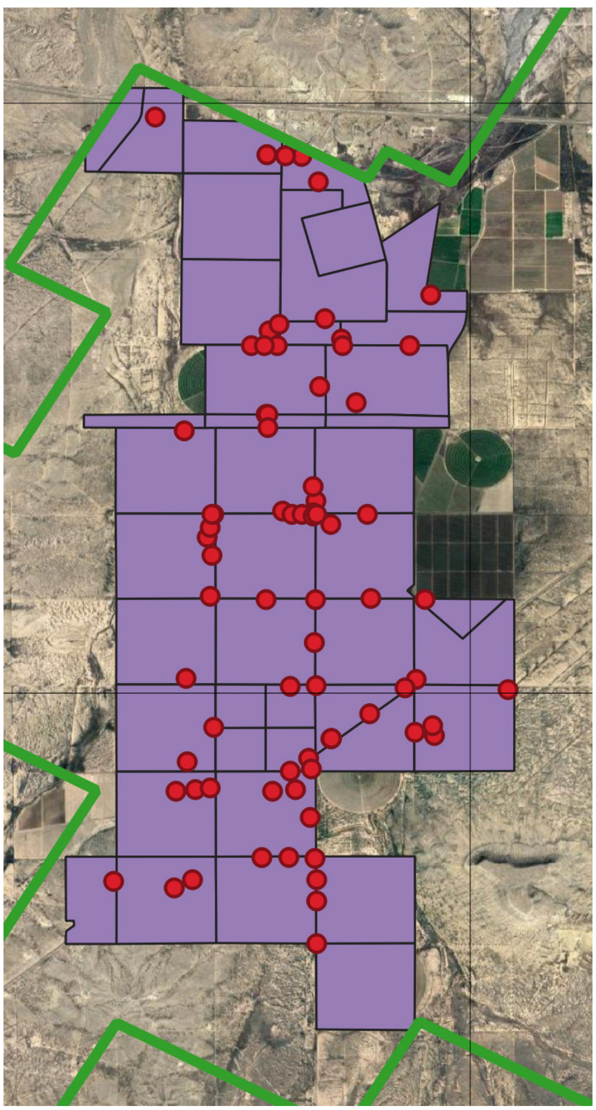

Figure 5. Parcels and wells in the Leon-Belding Productive Zone.

Once we harmonized the data, we then calculated hypothetical correlative allocations in several different ways for the productive zone in Groundwater Management Zone 1: (1) on a per parcel basis, (2) on a per owner basis for parcels with wells, and (3) on a per owner basis for all parcels regardless of having wells.

Results

As of July 2023, the Middle Pecos Groundwater Conservation District had issued 102 well permits for Management Zone 1. The total permitted pumping in Management Zone 1 was 87,242.86 acre-feet per year. Among those 102 well permits, 97 are associated with wells pumping from the Edwards-Trinity (Plateau) Aquifer, with a total permitted pumping of 78,289 acre-feet per year. After we removed well records without valid well permit holder entry or with zero permitted pumping, we were left with 82 well permits and a total permitted pumping of 75,794.5 acre-feet per year.

Based on permitted amounts and locations, we divided parcels in Management Zone 1 into those inside the productive zone and those outside of the zone (Figure 4). Of the total number of permitted wells, 68 were in the productive zone, constituting 73,199.5 acre-feet per year of permitted production, about 97 percent of the total permitted amount in Management Zone 1.

A total of 29 parcels had at least one permitted well within its boundaries, with total permitted pumping per parcel ranging from 15 to 8,005 acre-feet per year with an average of 2,580 acre-feet per year (Table 1). The area of these parcels ranged from 121 to 656 acres with an average of 503 acres, resulting in hypothetical correlative allocations ranging from 0.04 to 34.1 acre-feet per year per acre with an average of 6.13 and a median of 3.58 (Table 1, Figure 6).

Most groundwater conservation districts require that properties be contiguous to produce larger amounts of water for both coupled and decoupled correlative allocations. This is one of the tenants of the Reasonable Use Doctrine where reasonable production from an aquifer is tied to the property above it. Therefore, we grouped properties with the same or similar ownership and calculated apparent correlative allocations on this basis. We did this in two ways: (1) for properties with permitted wells and (2) for properties regardless of whether they had permitted wells. We erred on the side of lumping rather than splitting ownership for this proof-of-concept analysis since some landowners operated under various company names.

Ultimately, there really was not much of a difference between properties with wells and properties with and without wells since most properties had wells. In all, hypothetical correlative allocations range from 0.04 to 20.23 acre-feet per acre per year (Table 2).

Table 1. Total permitted production, area, and hypothetical correlative allocation by parcel for the Leon-Belding Productive Zone.

PARCEL	PERMITTED PRODUCTION (acre-feet per year)	PARCEL AREA (acres)	HYPOTHETICAL CORRELATIVE ALLOCATION (acre-feet per year per acre)
1	15.1	134.4	0.11
2	1,678.0	639.0	2.63
3	4,255.0	644.8	6.60
4	66.0	646.4	0.10
5	5,690.0	639.1	8.90
6	2,150.0	642.4	3.35
7	2,683.4	630.9	4.25
8	1,624.0	642.4	2.53
9	922.4	647.2	1.43
10	640.0	653.1	0.98
11	80.4	161.3	0.50
12	5,596.1	164.1	34.10
13	3,707.3	263.1	14.09
14	5,710.0	651.8	8.76
15	2,398.0	644.3	3.72
16	320.0	329.7	0.97
17	640.0	652.9	0.98
18	3,853.0	655.7	5.88
19	3,568.0	650.0	5.49
20	2,129.0	642.7	3.31
21	15.0	354.2	0.04
22	1,273.0	371.3	3.43
23	3,090.0	635.4	4.86
24	8,005.0	632.6	12.65
25	812.0	644.9	1.26
26	948.0	120.9	7.84
27	7,400.0	365.8	20.23
28	2,971.0	234.4	12.67
29	960.0	637.4	1.51
minimum	15.0	120.9	0.04
maximum	8005.0	655.7	34.10
median	2139.5	639.1	3.58
mean	2580.0	503.4	6.13

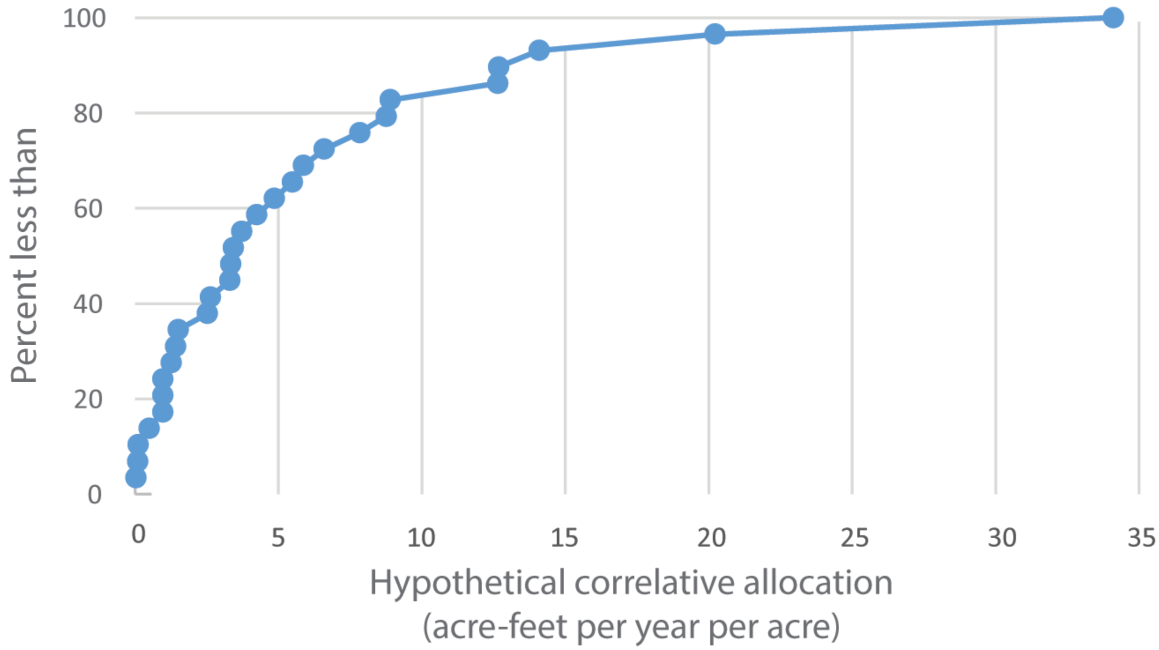

Figure 6. Cumulative distribution function for hypothetical correlative allocations by parcel in the Leon-Belding productive zone.

Table 2. Permitted production and hypothetical correlative allocations for (A) permit holder for parcels with wells and (B) permit holder for properties with and without wells for the Leon-Belding Productive Zone.

PERMIT HOLDER	PERMITTED PRODUCTION (acre-feet per year)	HYPOTHETICAL CORRELATIVE ALLOCATION A (acre-feet per year per acre)	HYPOTHETICAL CORRELATIVE ALLOCATION B (acre-feet per year per acre)
A	7,767	2.94	2.85
B	46,736	4.81	4.40
C	9,041	3.28	3.28
D	7,400	20.23	20.23
E	2,240	0.77	0.77
F	15	0.04	0.04

Options for Implementing Correlative Allocations

In all options considered, we divide the district's Management Zone 1 into two areas: (1) the area inside the Leon-Belding productive zone and (2) the area outside the Leon-Belding productive zone. First, we discuss options for the area inside the Leon-Belding productive zone and then discuss options for the Leon-Belding productive zone.

HONOR THE HIGHEST PARCEL

One approach would be to apply the highest hypothetical correlative allocation from all the parcels to all the other parcels. This would mean applying 34.1 acre-feet per acre (Table 2) across the productive zone. However, this would result in a permitted total of about 673,000 acre-feet per year, far above the carrying capacity of the system. The district could choose a lower hypothetical correlative allocation (using the average would result in about 121,000 acre-feet per year of total production) but would probably face takings lawsuits since those would larger allocations would end up with less water than currently permitted.

HONOR THE HIGHEST (OR SECOND-HIGHEST…) LUMPED PARCEL

Another approach would be to apply the highest hypothetical correlative allocation from the lumped ownership analysis. This would mean applying 20.23 acre-feet per acre per year (Table 2) across the productive zone resulting in a potential permitted total of about 400,000 acre-feet per year. That is substantially greater (5.5 times) than current permitted amounts. If, instead, we used the second highest number, 4.81 acre-feet per acre per year, the potential production total comes in at about 95,000 acre-feet per year, a more manageable amount and only 30 percent higher than currently permitted amounts.

It is unclear why Permit Holder D was permitted so much water since their crops are similar to other permit holders in the area. It may be that their historic use allocation applied to a greater irrigation area than that inside Management Zone 1 now. If the permit holder is indeed using that amount of water or close to that amount, then perhaps the district (or others) could help this permit holder use water more efficiently to come into compliance with a lower correlative allocation. Another option is to grandfather this property at a higher rate and assign correlative allocations at the second-highest total.

HONOR EACH LUMPED PARCEL

The history of groundwater use in the Leon-Belding productive zone is interesting in that the aquifer forced the sustainable use of the system long before a groundwater conservation district was formed (Mace and others 2020, Mace 2022). Irrigated agriculture came into an equilibrium in the productive zone based on the underlying structure and aquifer productivity. Operating under the assumption that the system has self-optimized to local hydrogeology, then the correlative allocations for the parcels or lumped ownership reflects that optimization. In this case, the district could simply convert current permits into correlative allocations. The benefit of this approach is that it protects everyone's current permitted amounts and caps production at those amounts.

Conclusions

Correlative allocations have a long history in Texas. Today, about 60 percent of groundwater conservation districts employ correlative allocations in some form in their rules with a median correlative allocation of 1.5 acre-feet per acre per year. Correlative allocations ranged from 0.04 to more than 90 acre-feet per acre per year with 25th, 75th, and 90th percentiles of 0.5, 3, and 8 acre-feet per acre per year, respectively.

Some districts give a correlative allocation with a process to request additional production above that allocation while others have time-based allocations (one allocation before a certain date and another after that date) or do not require historic use permits to adhere to newer allocation rules. Other districts have different allocations for different uses or exempt certain uses, such as public water supply, from allocation rules. Yet other districts employ equations to define the correlative allocation as a function of acreage and spacing requirements. One district varies its correlative allocation according to acreage and sand thickness while another bases it on crop type. One district pays landowners on a per acre basis to not use their correlative allocation for a defined number of years into the future. Districts employ correlative allocations in a variety of hydrogeologic settings, including karst aquifers.

We identified two broad categories of correlative allocations in Texas, those decoupled from desired future conditions and those coupled to desired future conditions. Districts assign coupled correlative allocations such that the modeled available groundwater amount would not be exceeded. Only five districts have coupled correlative allocations for all or some of their aquifers, and each one couples to the desired future condition in different ways.

We also analyzed how permits to produce from the Edwards-Trinity (Plateau) Aquifer in Management Zone 1 in the Middle Pecos Groundwater Conservation District could be converted to correlative allocations. We did this by defining a Leon-Belding Productive Zone, dividing wells and land parcels as either inside or outside the zone, and assessed different ways groundwater use could be allocated by acreage, thus providing a defined cap on groundwater production in the productive zone while honoring existing permitted use.

A challenge with using correlative allocations is that it may result in small amounts of water on a per acre basis when the modeled available groundwater is spread across a large geographic area. Sustainable groundwater production would only make this number smaller and more challenging to achieve through management. However, there are several benefits, namely that all landowners over the aquifer would have a defined fair share of groundwater with the choice to use, lease, sell, or conserve it in place for later use or other benefits. Correlative allocations force large producers and exporters to accrue the appropriate number of allocations to provide water for their projects rather than buying the minimum amount of land to produce the maximum amount of water. Furthermore, groundwater export may be more palatable to local landowners if they know that they still have a defined allocation. Once correlative allocations are defined, a water market can develop to meet development or environmental goals. Finally, providing all landowners with a fair share of the water underneath their property likely helps groundwater conservation districts defend their management decisions in court.

The Pecos River Valley in Texas © Riverwalker, Adobe Stock

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Appendix A: Correlative Allocations

(CA = correlative allocation in acre-feet per acre per year, * year refers to the year of the most recently available rules)

DISTRICT	YEAR*	CA	NOTES
Bandera County River Authority and Groundwater District	2022	1	
Barton Springs/Edwards Aquifer Conservation District	2023	-	
Bee Groundwater Conservation District	2012	16.14	
Blanco-Pedernales Groundwater Conservation District	2017	-	
Bluebonnet Groundwater Conservation District	2023	-	
Brazoria County Groundwater Conservation District	2019	-	
Brazos Valley Groundwater Conservation District	2023	95	new permits that need to stay 50 feet from an existing well
		189	new permits that need to stay 50 feet from a property line
		2	agricultural historic use
Brewster County Groundwater Conservation District	2023	0.15	less than 10 acres, non-municipal
Brush Country Groundwater Conservation District	2018	2.5	
Calhoun County Groundwater Conservation District	2024	0.5	
Central Texas Groundwater Conservation District	2019	1	Ellenburger-San Saba
		0.5	other aquifers
Clear Fork Groundwater Conservation District	2013	3	
Clearwater Underground Water Conservation District	2016	-	
Coastal Bend Groundwater Conservation District	2023	0.26	
Coastal Plains Groundwater Conservation District	2004	-	
Coke County Underground Water Conservation District	1989	-	
Colorado County Groundwater Conservation District	2015	10.5	
		12	
Comal Trinity Groundwater Conservation District	2020	-	
Corpus Christi Aquifer Storage and Recovery Conservation District	2016	0.04	
Cow Creek Groundwater Conservation District	2024	0.8	everything but the Lower Trinity
		0.4	Lower Trinity
Crockett County Groundwater Conservation District	2013	-	
Culberson County Groundwater Conservation District	2012	5	agricultural use
Duval County Groundwater Conservation District	2018	2	
Evergreen Underground Water Conservation District	2023	2	
Fayette County Groundwater Conservation District	2014	2	
Garza County Underground Water Conservation District	1998	-	
Gateway Groundwater Conservation District	2024	2	

DISTRICT	YEAR*	CA	NOTES
Glasscock Groundwater Conservation District	2023	3.2	
Goliad County Groundwater Conservation District	2016	0.5	
Gonzales County Underground Water Conservation District	2023	1	various variations with a global 1 acre-feet per acre per year
Guadalupe County Groundwater Conservation District	2023	various	Carrizo; depends on sand thickness
		0.5	Wilcox
Hays Trinity Groundwater Conservation District	2023	-	
Headwaters Groundwater Conservation District	2024	0.2	inside East Kerr Management Zone
		0.25	outside East Kerr Management Zone
Hemphill County Underground Water Conservation District	2023	0.5	sunflowers
		1	wheat
		1	cotton
		1	haygrazer
		1	sorghum
		1	soybean
		2	corn
		2	peanuts
		3	alfalfa
Hickory Underground Water Conservation District No. 1	2009	-	
High Plains Underground Water Conservation District No. 1	2023	1.5	with a "conservation reserve"
Hill Country Underground Water Conservation District	2023	0.5	for contiguous tract size of 10 acres or less
		1	for contiguous tract size of more than 10 acres
Hudspeth County Underground Water Conservation District No. 1	2016	4	under certain conditions
		0.5	for acreage in suspended lands status
Irion County Water Conservation District	2023	>4	permits for more than this triggers more scientific information for permit consideration
Jeff Davis County Underground Water Conservation District	2006	2	Igneous Aquifer
		2	Edwards-Trinity Aquifer
		2	Rustler Downdip
		1	West Texas Bolsons
Kenedy County Groundwater Conservation District	2023	0.75	Class D Production Well administratively complete on or after March 21, 2018
		0.75	Class D Zone Production Well screened to produce from the GCML1 Zone
		0.75	Class D Non-Zone Production Permit
		1.24	Class D Zone Production Well screened to produce from the GCUL1 Zone

DISTRICT	YEAR*	CA	NOTES
Kimble County Groundwater Conservation District	2022	>3	permits for more than this triggers more scientific information for permit consideration
Kinney County Groundwater Conservation District	2023	-	
Lipan-Kickapoo Water Conservation District	2007	-	
Live Oak Underground Water Conservation District	2011	2	
Llano Estacado Underground Water Conservation District	?	16.13	
Lone Star Groundwater Conservation District	2022	-	
Lone Wolf Groundwater Conservation District	2020	-	
Lost Pines Groundwater Conservation District	2023	0.5	Calvert Bluff
		0.8	Carrizo
		0.5	Hooper
		0.2	Queen City
		0.3	Sparta
		1.6	Simsboro
Lower Trinity Groundwater Conservation District	2023	-	
McMullen Groundwater Conservation District	2012	0.5	max; can petition for more
Medina County Groundwater Conservation District	2017	2	Leona Gravel before September 19, 2012
		0.5	Leona Gravel on or after September 19, 2012
		2	Carrizo-Wilcox
		1	Trinity Aquifer
Menard County Underground Water District	2013	-	
Mesa Underground Water Conservation District	2014	4	
Mesquite Groundwater Conservation District	2015	-	
Middle Pecos Groundwater Conservation District	2023	-	
Middle Trinity Groundwater Conservation District	2023	3	
		6	for certain retail public utilities
Mid-East Texas Groundwater Conservation District	2019	3	
Neches and Trinity Valleys Groundwater Conservation District		-	
North Plains Groundwater Conservation District	2023	1.5	
North Texas Groundwater Conservation District	2022	-	
Northern Trinity Groundwater Conservation District	2023	-	
Panhandle Groundwater Conservation District	2024	1	
Panola County Groundwater Conservation District	2021	-	
Pecan Valley Groundwater Conservation District	2023	1	wells greater than 700 feet deep; screen set at 500 feet or deeper; no limitation on TDS
		2	wells greater than 700 feet deep; screen set at 500 feet or deeper; 1,000 to 4,999 ppm TDS

DISTRICT	YEAR*	CA	NOTES
		5	wells greater than 700 feet deep; screen set at 500 feet or deeper; 5,000 to 10,000 ppm TDS
		10	wells greater than 700 feet deep; screen set at 500 feet or deeper; greater than 10,000 ppm TDS
Permian Basin Underground Water Conservation District	2023	-	
Pineywoods Groundwater Conservation District	2016	-	
Plateau Underground Water Conservation and Supply District	2016	1	
Plum Creek Conservation District	2018	0.5	
Post Oak Savannah Groundwater Conservation District	2023	2	does not apply to historic use permits
Prairielands Groundwater Conservation District	2023	0.15	
Presidio County Underground Water Conservation District	2023	2	Igneous Aquifer
		1	West Texas Bolsons
		3	Presidio/Redford Bolson
Real-Edwards Conservation and Reclamation District	2023	2	does not apply to public water supply wells
Red River Groundwater Conservation District	2022	-	
Red Sands Groundwater Conservation District	2009	2	
Reeves County Groundwater Conservation District	2023	6	
Refugio Groundwater Conservation District	2024	0.5	also has a pumping rate limit based on acreage
Rolling Plains Groundwater Conservation District	2003	3	
Rusk County Groundwater Conservation District	2023	378	equation based; non-linear
		189	equation based; non-linear
San Patricio County Groundwater Conservation District	2016	-	
Sandy Land Underground Water Conservation District	2023	8.1	
		4	Dockum
Santa Rita Underground Water Conservation District	2023	-	
Saratoga Underground Water Conservation District	2023	-	
South Plains Underground Water Conservation District	2009	4	
Southeast Texas Groundwater Conservation District	2023	-	
Southern Trinity Groundwater Conservation District	2021	2.5	existing and historic agricultural use
Southwestern Travis County Groundwater Conservation District	2023	-	
Starr County Groundwater Conservation District	2020	-	
Sterling County Underground Water Conservation District	2023	-	
Sutton County Underground Water Conservation District	2018	1	
Terrell County Groundwater Conservation District	2023	-	
Texana Groundwater Conservation District	2023	0.5	

DISTRICT	YEAR*	CA	NOTES
Trinity Glen Rose Groundwater Conservation District	2023	1	
Upper Trinity Groundwater Conservation District	2021	-	
Uvalde County Underground Water Conservation District	2023	2.5	irrigation
Victoria County Groundwater Conservation District	2024	0.5	for use of a non-exempt-use well
		0.5	for non-historic use of a non-exempt-use well
		0.75	for historic use of a non-exempt-use well
Wes-Tex Groundwater Conservation District	2019	-	
Wintergarden Groundwater Conservation District	2023	2.5	agricultural and other uses

Appendix B: Acreage and Production Requirements for Certain Exempt Uses

(Q = maximum production in gallons per day, A_m = minimum acreage, * year refers to the year of the most recently available rules)

DISTRICT	YEAR*	Q	A_M
Mid-East Texas Groundwater Conservation District	2019	50,400	- -
Neches and Trinity Valleys Groundwater Conservation District		36,000	- -
North Plains Groundwater Conservation District	2023	25,000	- -
North Texas Groundwater Conservation District	2022	25,000	- -
Northern Trinity Groundwater Conservation District	2023	25,000	- -
Panhandle Groundwater Conservation District	2024	25,000	- -
Panola County Groundwater Conservation District	2021	25,000	- -
Pecan Valley Groundwater Conservation District	2023	43,200	- -
Permian Basin Underground Water Conservation District	2023	25,000	> 10 acres
Pineywoods Groundwater Conservation District	2016	25,000	- -
Plateau Underground Water Conservation and Supply District	2016	25,000	- -
Plum Creek Conservation District	2018	25,000	- -
Post Oak Savannah Groundwater Conservation District	2023	50,000	> 10 acres for domestic use
		25,000	> 10 acres for livestock and poultry
Prairielands Groundwater Conservation District	2023	25,000	> 2 acres
Presidio County Underground Water Conservation District	2023	25,000	> 10 acres
Real-Edwards Conservation and Reclamation District	2023	25,000	> 10 acres
Red River Groundwater Conservation District	2022	25,000	- -
Red Sands Groundwater Conservation District	2009	25,000	- -
Reeves County Groundwater Conservation District	2023	28,800	- -
Refugio Groundwater Conservation District	2024	-	- -
Rolling Plains Groundwater Conservation District	2003	25,000	> 10 acres
Rusk County Groundwater Conservation District	2023	25,000	- -
San Patricio County Groundwater Conservation District	2016	25,000	- -
Sandy Land Underground Water Conservation District	2023	25,000	- -
Santa Rita Underground Water Conservation District	2023	25,000	> 10 acres
Saratoga Underground Water Conservation District	2023	25,000	> 2 acres
South Plains Underground Water Conservation District	2009	25,000	- -
Southeast Texas Groundwater Conservation District	2023	100,000	- -
Southern Trinity Groundwater Conservation District	2021	25,000	- - definition says 100,000, but rule says 25,000

DISTRICT	YEAR*	Q	A_M
Southwestern Travis County Groundwater Conservation District	2023	25,000	> 10 acres
Starr County Groundwater Conservation District	2020	25,000	> 1.7 acres domestic use
		25,000	> 10 acres livestock or poultry
Sterling County Underground Water Conservation District	2023	25,000	> 10 acres
Sutton County Underground Water Conservation District	2018	25,000	> 10 acres
Terrell County Groundwater Conservation District	2023	25,000	> 10 acres
Texana Groundwater Conservation District	2023	35,000	- -
Trinity Glen Rose Groundwater Conservation District	2023	10,000	- -
Upper Trinity Groundwater Conservation District	2021	25,000	- -
Uvalde County Underground Water Conservation District	2023	25,000	- -
Victoria County Groundwater Conservation District	2024	-	- -
Wes-Tex Groundwater Conservation District	2019	25,000	- -
Wintergarden Groundwater Conservation District	2023	25,000	> 10 acres

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