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A NEW FRONTIER IN TEXAS:
MANAGING AND REGULATING
BRACKISH GROUNDWATER

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Abstract

Providing access to clean water is a grand challenge in engineering, and supplying sufficient, clean water is a problem around the globe. This challenge is visible in Texas, where drought coincides with population growth and increases in water demand. The 2012 Texas State Water Plan reports a 2,700 million cubic meters (MCM) gap between fresh water supply and demand in 2010, a number predicted to grow to 3,100 MCM by 2060 if new sources of water are not developed or substantial decreases in demand are not obtained. Due to the inherent political difficulty of decreasing water demand, policy makers and water providers are evaluating new water sources, including wastewater for direct or indirect reuse and brackish groundwater for desalination or direct use. It has been estimated that Texas aquifers contain more than 3,300,000 MCM of brackish groundwater, which, if converted to freshwater, could meet current consumption needs for 150 years, albeit at a greater water treatment cost. Using Texas as a case study, this article addresses which policies are desirable to best manage the supply of brackish groundwater. We review the geological, technical, and legal contexts of groundwater in Texas and situate brackish groundwater within those constructs. We consider efforts by other U.S. states to regulate brackish groundwater and identify desirable goals for its management, including facilitating access to and incentivizing use of brackish groundwater and protecting fresh water aquifers from potential saline intrusion related to brackish groundwater production. Various brackish groundwater policies are examined, and policy recommendations regarding use of the resource are offered.

1.0. Introduction

The 2012 Texas State Water Plan reports a 2,700 million cubic meters (MCM) gap between fresh water supply and demand in 2010 (Texas Water Development Board 2012). This unmet water need may increase in times of drought and provides an excellent context for the present water management case study. In order to close the water gap, new sources of water are being evaluated, including wastewater for direct or indirect reuse and brackish groundwater¹ for desalination or direct use. It is estimated that Texas aquifers contain more than 3,300,000 MCM of brackish groundwater, which, if converted to freshwater, could meet current consumption needs for 150 years, albeit at a greater water treatment cost (Karagiannis and Soldatos 2008). The State of Texas has funded efforts to increase knowledge and understanding of brackish groundwater resources and the technologies needed to use them effectively. As use of brackish groundwater increases, regulators and water users debate best management practices for the new resource. Because regulation of water in the United States is largely under the jurisdiction of the individual states, matters of emerging water stresses and growing demand in Texas rest squarely on the shoulders of state lawmakers. Indeed, stakeholders in Texas—including landowners, agricultural producers, municipalities, and industry—are closely following the courts and legislature to determine how they may best ensure water security into the future. Texas has joined other jurisdictions already utilizing brackish groundwater, and it is likely that other arid and semiarid regions will look to the Texas case study when determining policies for effective utilization of brackish groundwater to enhance water security.

This article addresses which policies—regulatory and otherwise—are desirable to best manage brackish groundwater. We begin, in Section 2, by reviewing the geological, technical, and legal contexts of fresh and brackish groundwater, taking into account Texas’s unique context. In Section 3, we examine efforts by other U.S. states to regulate brackish groundwater and draw comparative lessons where possible. We then, in Section 4, identify desirable goals for the management of brackish groundwater, including facilitating access to and incentivizing use of

¹ Brackish groundwater is, generally, groundwater that is more salty than drinking water but not as salty as seawater, often denoted as water between 1,000-10,000 ppm TDS. More detailed discussion of what constitutes brackish groundwater in common usage and under Texas law are provided in the next section and in Section 5.1.

brackish groundwater and protecting fresh water aquifers from potential saline intrusion related to brackish groundwater production. In Section 5, we examine various brackish groundwater policies that have been proposed in Texas, and we conclude in Section 6 by offering policy recommendations regarding use of the resource. Although we acknowledge that Texas' system of groundwater governance and management impedes market forces, we discuss policies that would work within the current institutional, political, and cultural constraints in hopes of offering insights for other regions considering brackish water development.

2.0. Groundwater in Texas

2.1. Geological and Technological Context

Groundwater is a vital resource. In 2010, more than 50% of the estimated 17,000 MCM of the water used in Texas was groundwater, a rapidly depleting resource in some parts of the state (Texas Water Development Board 2012). With groundwater tables subsiding and surface water fully allocated, Texans are now considering unconventional water resources, including brackish groundwater (Hightower, Kottenstette, and Webb 2005). Some have even declared a “general consensus among all stakeholders” that brackish groundwater must be developed where feasible (Steinbach 2013). This development includes use of brackish groundwater directly, if possible, and desalination of brackish groundwater to produce fresh water. The Texas Commission on Environmental Quality (TCEQ), the state agency tasked with regulating desalination plants, is moving forward to facilitate development, streamlining the approval processes for brackish groundwater desalination facilities (Texas House Natural Resources Committee 2015). Many in Texas, including major municipalities and industry, have started to tap the 3,300,000 MCM reserve that the state's brackish groundwater supply offers.

Brackish groundwater is groundwater that has a high concentration of total dissolved solids (TDS)²—primarily the common salt sodium chloride. Although a quantitative description of brackish groundwater is debated, it is often defined as water containing between 1,000 and

² TDS is often reported as parts per million (ppm). For example, 500 ppm would mean 500 parts salt per one million parts water.

10,000 parts per million (ppm) TDS.³ (For reference, seawater contains ~35,000 ppm TDS.) The issue of what, exactly, constitutes brackish groundwater is one of the questions policymakers are struggling to resolve; the debate is discussed at greater length in Section 5.1. Brackish groundwater is generally (1) fresh groundwater that acquired salts as it migrated through aquifer matrices (e.g., halite or gypsum); (2) intruded saline groundwater that was diluted in fresh water aquifers (often a result of over-pumping fresh coastal aquifers or open well boreholes that allow mixing between strata); (3) shallow, often unconfined, aquifers that have increased salinity as a result of agricultural/industry practices or road salt use; or (4) water in isolated, often deep, connate or “fossil aquifers” that are no longer recharged by surface water (U.S. Geological Survey 2014a).

Brackish aquifers are located throughout much the United States.⁴ In 2009, the Texas Legislature funded the Brackish Resources Aquifer Characterization System (BRACS), a Texas Water Development Board (TWDB) program designed to map and characterize potential sources of brackish groundwater for desalination in Texas (TWDB 2015a). Thus far, BRACS has mapped and characterized the Pecos, Gulf Coast, Queen City, and Sparta aquifers (Meyer, Wise, and Kalaswad 2012; Meyer et al. 2014; Wise 2014).

³ This level of TDS for brackish groundwater is not a statutory or otherwise statewide definition in Texas, although the 1,000 ppm TDS benchmark has been used in numerous studies in the state over the last 15 years. There are also a number of groundwater conservation districts that define brackish water using 1,000 ppm TDS as a lower limit. See, e.g., Rules of the Evergreen Groundwater Conservation District (2009); Rules of the Gonzales County Underground Water Conservation District (2010).

⁴ A national study of brackish groundwater was completed in the 1960s. In an effort to update and improve understanding of the location and character of these resources, the U.S. Department of the Interior is conducting a national assessment, which is due in September 2016 (U.S. Geological Survey 2014b).

Figure 1. Map of Brackish Aquifers in Texas

Source: Lateral extent of brackish aquifers and detailed county boundaries, including groundwater conservation districts with special rules for brackish groundwater. Shapefiles are from the Texas Water Development Board and the Texas Natural Resources Information System.

Although an isolated formation may contain only brackish groundwater, a salinity gradient is observed across some aquifers, which may make regulation and management more complex. For example, the Queen City aquifer has a TDS concentration that varies from 300–700 ppm in the north near its outcrop to > 10,000 ppm TDS in the south (Wise 2014). This situation makes disparate treatment of fresh and brackish groundwater difficult, as pumping from the brackish section of the aquifer may have direct and potentially adverse effects on water in the fresh part of the aquifer. Additionally, the depth and thickness of the aquifer increases toward the south, reaching a thickness of 430 m in the south and a top depth of 980 m below ground surface (Wise 2014). Variations in aquifer depth and TDS concentrations have important implications for the cost to acquire and treat water, and these costs depend not only upon the target aquifer but also the location within the target aquifer.

Costs of wells increase with aquifer depth, as does the cost of reverse osmosis (RO) desalination with TDS concentration. Thus, some of the fresher water in the Queen City aquifer is not

considered brackish, and it is below the secondary maximum contaminant level (SMCL) for TDS set by the U.S. Environmental Protection Agency (EPA) for aesthetic acceptability purposes, 500 ppm (U.S. EPA 2015).⁵ In order to meet that standard, water with a salt concentration higher than 500 ppm must be either blended with lower salinity water or treated to remove salt. Treatment is normally accomplished with reverse osmosis, whereby water is forced under high pressure through a salt-rejecting membrane. As TDS concentration increases, higher pressure is needed, increasing operational costs (i.e., electricity). Thus, the cost of treating brackish groundwater rises with increasing TDS (LBG-Guyton Associates 2003; Jaber and Ahmed 2004; Karagiannis and Soldatos 2008).

Some industries may use brackish groundwater with minimal or no treatment. Untreated, low-salinity brackish water may be used for irrigation, (Texas House Natural Resources Committee 2015), and higher-salinity waters may be used for power plant cooling (Maulbetsch and DiFilippo 2010). Several oil and gas well operators are turning to brackish groundwater as an alternative source of water. Thus, the use of brackish water for hydraulic fracturing operations has increased, especially in the Eagle Ford, Permian, and Anadarko basins. Table 1 lists the counties with the highest estimated brackish groundwater use for hydraulic fracturing. Brackish water is more commonly used for hydraulic fracturing in the western part of the state, which lacks easy access to surface water. The Bureau of Economic Geology at the University of Texas at Austin reports that 20%, 30%, and 30% - 80% of the water used for hydraulic fracturing operations in 2012 in the Eagle Ford play and the Anadarko and Permian basins (respectively) is brackish (Bureau of Economic Geology 2012). Hydraulic fracturing operations in the eastern part of the state use less groundwater and less brackish water, with producers in the Barnett using only 3% brackish water.

⁵ SMCLs are not enforceable by the EPA; they are meant as guidelines to control compounds that contribute to taste, color, and odor of drinking water (U.S. EPA 2013). However, desalination plant operators often cite this number as their target effluent standard.

Table 1. Counties with the Highest Amount of Estimated Brackish Water Use for Hydraulic Fracturing in 2012

<i>County</i>	<i>GCD</i>	<i>Shale Play/Basin</i>	<i>Estimated Water Use (MCM)</i>	<i>Estimated Brackish Water Use (MCM)</i>
<i>Dimmit</i>	Wintergarden	Eagle Ford	9.87	1.97
<i>La Salle</i>	Wintergarden	Eagle Ford	8.71	1.74
<i>Karnes</i>	Evergreen	Eagle Ford	6.36	1.27
<i>Reeves</i>	Reeves	Permian	1.55	1.24
<i>Wheeler</i>	Panhandle	Anadarko	4.06	1.22
<i>Webb</i>	N/A	Eagle Ford	5.92	1.18
<i>Glasscock</i>	Glasscock	Permian	3.68	1.10
<i>Reagan</i>	Santa Rita	Permian	3.01	0.90
<i>McMullen</i>	McMullen	Eagle Ford	4.49	0.90
<i>Upton</i>	N/A	Permian	2.88	0.86
<i>Irion</i>	Irion	Permian	2.84	0.85
<i>Martin</i>	Permian Basin	Permian	2.73	0.82
<i>Loving</i>	N/A	Permian	0.89	0.71
<i>Gonzales</i>	Gonzales	Eagle Ford	3.27	0.65
<i>Midland</i>	N/A	Permian	2.15	0.64

Source: Brackish use volume was calculated by the TWDB using average well completion volume information from FracFocus.org and water source estimates from UT BEG (Bureau of Economic Geology 2012). (“N/A” indicates the county does not have a groundwater conservation district.)

The oil and gas industry is not the only water user looking for alternative sources as water demand and water scarcity increase in Texas. In this environment, the economics of brackish groundwater are becoming more favorable for water suppliers, such as municipalities and water utilities, who must remove salt prior to distribution. In Texas, construction of groundwater RO desalination plants (Figure 2) indicates that water suppliers are willing to pay more to treat impaired or brackish groundwater. These municipalities choose to pay the costs of advanced treatment rather than incur the costs of building additional water transportation infrastructure (dams, canals, and pipelines) or securing additional water rights.

Figure 2. Cumulative Production (Designed and Average) of Groundwater Desalination Plants in Texas

Source: Data from the TWDB Desalination Plant Database (TWDB 2010)

RO desalination can help alleviate water stress and potentially reduce withdrawals from fresh groundwater aquifers, but the process is not without economic and environmental costs.⁶ The energy and specialized materials and equipment used for RO are quite expensive. Recently, brackish desalination plants in El Paso and Brownsville were constructed at a cost of US\$91 million and US\$23 million to produce 57,000 and 23,000 m³ per day respectively (Arroyo and Shirazi 2012; Galbraith 2012; TWDB 2010). Further, the process creates a waste product (or brine) that can be saltier than seawater and must be properly disposed of. Near the coast, brine from desalination operations is often discharged into the ocean, where its high salinity and temperature can impact marine life (Lattemann and Höpner 2008). Inland, brine may be injected into disposal wells (Texas Administrative Code §3.9), which are currently under scrutiny and

⁶ Though it does have an environmental impact, it is worth noting that brackish groundwater desalination has also been shown to have a significantly lower global environmental impact than seawater desalination, mainly due to the lower electricity requirement and subsequently lower CO₂ emissions (Muñoz and Fernández-Alba 2008).

additional regulation because of their connection to seismic activity (Ellsworth 2013; Frohlich, Hayward, Stump, and Potter 2011).

Despite the additional costs, RO desalination is helping meet water demand and water quality requirements across Texas. Most desalination plants are small operations (<4,000 m³ per day) that produce drinking water (TWDB 2010), but there are larger operations as well. The City of El Paso blends brackish groundwater RO permeate with brackish water to produce up to 104,000 m³ per day, which could supply 35% of the city's water supply (TWDB 2010). San Antonio is building a desalination facility in South Bexar County at a total cost of US\$411.4 million to produce 114,000 m³ per day, increasing the city's current water supply by 14% (San Antonio Water System 2015). The TWDB is considering additional desalination plants to meet water needs (TWDB 2015c).

2.2. Groundwater Regulation in Texas

2.2.1. State Law

Advancements in the economic development of brackish groundwater in Texas are occurring within a complicated and potentially unsustainable governance regime for groundwater. Texas regulates surface water and groundwater separately, with almost⁷ no legal recognition the resources are connected. Whereas surface water is owned by the State of Texas and apportioned via prior appropriation (the doctrine often described as “first in time, first in right”), groundwater is the private property of the land surface owner. Using separate legal regimes to govern this unitary resource is nonsensical and fails to account for the impact that consumption of surface water may have on groundwater and vice versa. Even the U.S. Supreme Court has recognized that “groundwater and surface water are physically interrelated as integral parts of the hydrologic cycle” (*Cappaert v. U.S.*).

The law governing groundwater in Texas is underpinned by the absolute ownership doctrine and its corollary, the rule of capture. In essence, the absolute ownership rule, spelled out by the Texas

⁷ Exceptions to this are (1) §11.151, Texas Water Code, which orders the TCEQ to consider the effects, if any, on groundwater or groundwater recharge of a new permit to store, take, or divert surface water, and (2) §36.113(d), Texas Water Code, which requires GCDs to consider in granting a permit whether the proposed use of water unreasonably affects existing groundwater and surface water resources or existing permit holders (Texas Water Code, §§11.151; 36.113).

Supreme Court in 1904 in *Houston & Texas. Cent. Ry. Co. v. East*, provides that a landowner owns the water under his land and can do as he pleases with it:

An owner of soil may divert percolating water, consume or cut it off, with impunity. It is the same as land, and cannot be distinguished in law from land. So the owner of land is the absolute owner of the soil and of percolating water, which is a part of, and not different from, the soil.

This rule has been confirmed in subsequent cases throughout the last century. Likewise, the doctrine's corollary, the rule of capture, provides that a landowner may take all the water he can capture under his land and incurs no liability to his neighbors even if the landowner's actions deprive the neighbors of the water's use. Case law has carved out a few minimal limitations on the rule of capture in Texas: a landowner may not (1) maliciously take water for the sole purpose of injuring a neighbor, (2) negligently cause subsidence of another's land by his production, or (3) wantonly and willfully waste the water (*City of Corpus Christi v. City of Pleasanton*; *Friendswood Development Co. v. Smith-Southwest Industries, Inc.*).

The Texas Legislature explicitly stamped its approval on the ownership interest described by these long-standing common law rules in 2011, amending chapter 36 of the Texas Water Code to provide that "[t]he legislature recognizes that a landowner owns the groundwater below the surface of the landowner's land as real property" (Texas Water Code §36.002). Recent case law has reaffirmed the prominence of the absolute ownership rule and the rule of capture. In 2012, the Texas Supreme Court held definitively in *Edwards Aquifer Authority v. Day* that groundwater is owned in place by the landowner.

Despite the presence of strong and consistent affirmations of private property rights, groundwater rights in Texas are still subject to some degree of control by the legislature and the courts. The Conservation Amendment of the Texas Constitution requires the state to preserve and conserve water resources for the benefit of the people of Texas (Texas Const. art. XVI, §59). The legislature has chosen to achieve this constitutional objective by authorizing the creation of groundwater conservation districts (GCDs) (Texas Const. art. XVI, §59(a); Texas Water Code

§36.0015). Pursuant to chapter 36 of the Texas Water Code, GCDs are authorized to adopt rules imposing requirements for well drilling and spacing or limiting production to achieve certain management objectives. The legislature has chosen to exempt certain types of wells from permitting requirements in GCD rules, including domestic wells meeting specified conditions or wells for certain oil and gas exploratory activities or mining activities (Texas Water Code §36.0017). However, the exemptions are a floor, not a ceiling, and GCDs have significant discretion in developing their rules.

Approximately 100 GCDs have been created in Texas, but there remain portions of the state that are not within the jurisdiction of a district. Thus, groundwater regulation and management in Texas depend, in great part, on the location of the groundwater. If the site is within a GCD, the GCD's rules apply to the production and use of the groundwater. If the site is not located within a GCD, the rule of capture applies, and the landowner (or a lessee) may drill a water well and produce as much groundwater as can be put to beneficial use, subject to the common law limitations described above, statutory requirements for drilling and completing the well, and any agreements with the surface owner. Indeed, despite Texas' strong attachment to the rule of capture, instances of this practice are currently causing public controversy in the state.⁸

Although it is clear GCDs have the authority to regulate groundwater production within their boundaries, *Edwards Aquifer Authority v. Day* and subsequent cases have raised questions about the extent to which GCDs may use their authority. In *Day*, the Texas Supreme Court held definitively that landowners own the groundwater in place beneath their land and stated that a restriction on that ownership interest *could* constitute an uncompensated governmental taking under the Texas Constitution. In arriving at this conclusion, the court acknowledged the authority of GCDs to regulate groundwater production as authorized by law, but it failed to delineate specifically where proper regulation became an impermissible taking. In *Edwards Aquifer Authority v. Bragg* (2013), Glenn and JoLynn Bragg asked the courts to determine whether the

⁸ In January 2015, controversy arose concerning plans by a Houston-based company to pump $0.22 \text{ m}^3 \text{ s}^{-1}$ from wells drilled into portions of the Trinity Aquifer that are not subject to governance by a GCD, potentially causing a severe drop in the water table and drying up nearby residential wells. The region's state representative noted that the project "seems like it goes beyond the good will intention of the law," but there is little that anyone can do to slow or halt the project (Satija 2015).

Edwards Aquifer Authority's (EAA) reduction of the amount of groundwater they are permitted to produce from their land constitutes a taking of property rights without compensation. The district court found, and the Fourth Court of Appeals of Texas affirmed, that the EAA's action constituted a regulatory taking, though the two courts differed on the amount of and methodology for determining damages. In May 2014, the Texas Supreme Court declined to hear the case, leaving the Court of Appeal's decision in place. The precedent leaves open the possibility of enormous potential financial liabilities for groundwater districts and will make GCDs' responsibilities of managing and protecting groundwater in Texas very difficult, if not impossible.

Another uncertainty for GCDs and other stakeholders is how best to protect brackish aquifers from the disposal of oil and gas waste or brine. This issue was spotlighted recently in a Texas Supreme Court case in which industrial waste injected by the defendant into an aquifer formation more than 2,100 m below ground allegedly migrated across a neighbor's property line, potentially contaminating a saltwater aquifer belonging to the neighbor (*Environmental Processing Systems, L.C. v. FPL Farming Ltd*). The landowner argued that advances in desalination technology could make the saltwater drinkable, and thus the contamination potentially harmed the value of his property. As part of its response, the defendant cited prior case law to counter the proposition that "land ownership extends to the sky above and the earth's center below," (*Coastal Oil & Gas Corp. v. Garza Energy Trust*),⁹ staking out a position that would seem logically to contradict *Day's* holding that landowners own groundwater in place—or at least begs the question of the depth at which the property line is drawn. The Texas Supreme Court in a prior case, *Hastings Oil Co. v. Texas Co.*, upheld an injunction prohibiting subsurface trespass by an oil and gas company whose well crossed the property line underground. The Supreme Court ultimately resolved the *Environmental Processing Systems* case without addressing the question of whether deep subsurface wastewater migration is actionable as a common law trespass in Texas, but the case highlighted questions about environmental and private property protections for brackish groundwater that could easily arise again.

⁹ In *Coastal Oil & Gas Corp. v. Garza Energy Trust*, the Texas Supreme Court ruled against a group of landowners suing an oil and gas company for draining gas from beneath the group's adjacent property, because the rule of capture prevented the neighbors from recovering lost royalties on gas drained from their property. The court chose not to decide the larger question presented—whether subsurface hydraulic fracturing operations could give rise to an action for trespass.

The legal context and unresolved issues described above affect the manner and extent to which brackish groundwater supplies may be developed and the ability of GCDs to protect aquifers within their boundaries from harmful environmental impacts. The tasks of increasing water supply in response to growing demand, protecting underground water resources, and respecting private property rights must all be carried out within this complex and, at times, uncertain framework, with potentially very high costs. Furthermore, the idea of creating policy to incentivize brackish groundwater development contradicts a current system that does not value fresh groundwater—often more easily accessed and used than would be brackish groundwater—appropriately.

2.2.2. Groundwater Conservation District Rules

To understand GCD regulation of brackish groundwater, we reviewed all available GCD and subsidence district rules in place as of January 2015.¹⁰ Each GCD is authorized to adopt its own rules, and regimes vary widely across the state with regard to permit limits, pumping allowances, exemptions, metering, reporting, and water quality testing. Of the 96 GCDs for which rules were reviewed, nine districts (9.4%) provide regulations for brackish groundwater that differ from regulations for fresh groundwater (see Figure 1). The provisions in question range from broad, non-binding statements that purport to reserve the districts' right to provide for the disparate treatment of brackish groundwater and fresh groundwater to more detailed regulations regarding permitting (pumped volumes and well spacing), well testing, and monitoring of nearby fresh water wells, as summarized in Table 2.¹¹ It is noteworthy that over 90% of districts do not distinguish between brackish and fresh groundwater from a permitting standpoint.

¹⁰ Of the 100 GCDs and subsidence districts on the TWDB website, four GCDs had no rules posted online. Three of these GCDs are relatively new (Calhoun County GCD confirmed November 2014; Deep East Texas GCD and Reeves GCD created by Texas Senate in 2013, pending local election) and thus have no rules yet available. Kinney County GCD, which also does not post rules or have a website, was under discussion for dissolution or addition to the Edwards Aquifer Authority in 2005. The state performed an unfavorable audit on the Kinney County GCD in 2010. Thus, this study includes rules for 96 GCDs. Rules were searched for the terms “brackish,” “saline,” “salinity,” “dissolved solids,” and “salt.” “Salt” was most commonly present in statements banning contamination of fresh water aquifers with salt water or mention of salt water intrusion barriers to protect fresh water.

¹¹ The preambles to the rules of the Sterling County Underground Water Conservation District and the Irion County Water Conservation District both provide that the districts “may consider undesirable water or brackish water differently than fresh water.” These districts do not have substantive rules governing the current management of brackish water differently at this time. For that reason, they are not included in Table 2.

Districts that do provide specific rules for brackish groundwater generally have three overarching goals: (1) to incentivize pumping of brackish groundwater, (2) to protect fresh groundwater, and (3) to protect the aquifers from impacts related to desalination and brine disposal. Some GCDs already provide incentives for persons who wish to produce brackish groundwater (Table 2), often in the form of permits with longer terms or less stringent (or non-existent) pumping limits. For example, the Coastal Plains GCD allows for the issuance of permits to produce brackish groundwater for up to 10 years (Coastal Plains GCD Rule 6.12), which provides enhanced certainty of supply for projects that require significant infrastructure investment (e.g., desalination or pipelines). The maximum term for a fresh groundwater permit from the Coastal Plains GCD is three years (Coastal Plains GCD Rule 3.15[a][2]). Several GCDs also offer brackish groundwater production permits with no production limit or a higher limit (e.g., $\text{m}^3 \text{y}^{-1} \text{m}^{-2}$) compared to freshwater production limits (e.g., Coastal Plains GCD Rule 6.12; Evergreen Rules 5.4 and 6.10).

Table 2. Summary of GCD Rules Pertaining to Brackish Groundwater

<i>GCD</i>	<i>Permit Length</i>	<i>Production Limit</i>	<i>Well spacing</i>	<i>Reporting</i>	<i>Mechanical well tests</i>	<i>Brine disposal plan</i>	<i>Casing Requirements</i>	<i>Monitoring Wells</i>
<i>Barton Springs/ Edwards Aquifer</i>								○
<i>Coastal Plains</i>	○	○	○	○		○	○	○
<i>Evergreen</i>		○	○	○	○	○	○	○
<i>Gonzales County</i>				○	○	○		○
<i>Pecan Valley</i>		○		○				
<i>Plumb Creek</i>		○	○					
<i>Post Oak Savannah</i>		○						

Note: A “○” indicates the existence of specific rules for brackish groundwater wells.

Protecting fresh water supplies from impacts of production in brackish zones of mixed-salinity aquifers is another concern of GCDs. In order to monitor the effects that brackish groundwater pumping may have on nearby freshwater, some GCDs require reporting of well levels and salinity in the brackish well and/or nearby freshwater monitoring wells (Coastal Plains GCD Rule 6.12; Evergreen UWCD Rule 6.10[d]; Gonzales County Rule 14[b][8]). Casing requirements that isolate freshwater aquifers from the brackish well hole have also been adopted by two GCDs (Coastal Plains GCD Rule 6.12; Evergreen UWCD 6.10[c][2]). It is important to note that these protections, although justified in many cases, come at a cost to the brackish well owner.

Finally, GCDs are concerned with protecting the aquifers from impacts related to desalination and brine disposal. Rules addressing this concern are targeted specifically at wells that produce water for RO desalination. In RO, brackish or salt water is separated into two streams—a freshwater stream (that can be distributed as drinking water, for example) and a concentrated salt stream, or brine. As many desalination plants are inland, brine disposal is an important issue. Although it is possible to further concentrate the brine by removing the remaining water, leaving only solid waste that may be disposed of in a landfill, in practice, brine is often disposed of via injection wells (TWDB 2010). Some GCDs require the details of the brine disposal method in the brackish groundwater permit in order to ensure brine disposal practices do not endanger fresh

water resources (Coastal Plains GCD Rule 6.12; Evergreen UWCD Rule 6.10[b]; Gonzales County Rule 14[B][6][b]). The recent spill of nearly 14,000 m³ of salty produced water (from oil and gas operations) in North Dakota is a powerful example of why the protection of fresh water resources from salt-laden waste is recognized as a top priority (Associated Press 2015).¹²

It is interesting to note that there is limited overlap between counties with high brackish groundwater use (Table 1) and the GCDs with specific rules for brackish groundwater (Table 2), namely the Evergreen UWCD and Gonzales County UWCD. Additionally, many counties with high brackish groundwater use do not have a GCD in place (Webb, Upton, Loving, and Midland). In these counties, which operate under the rule of capture for groundwater, the use of brackish groundwater may be due to economics or long-term water planning decisions.

2.3. Limitations of the Current Institutional Framework

Sections 2.1 and 2.2 of this article describe the contours of groundwater management and regulation in Texas. The variables and stakeholders are myriad, and the policies and rules in place do not result in water pricing that reflects water quality or scarcity. Figure 3 represents the effects of these market impediments on water pricing and demand in Texas. We assume that, initially, the price of fresh water (λ) represents the marginal cost of water at point e_1 . Because Texas is water-scarce, there is little elasticity in the supply of water (represented by the steep slope of the supply curve). As demand increases due to population growth and economic development, and the current legal structure, in effect, fixes the price for water at λ (λ), an increase in the amount of water consumed (q_1) results. If, however, a market structure existed that allowed water rights holders to easily sell water for an increased cost when demand for water increased, a new equilibrium at point e_2 could be achieved. In our example, this resulting increase in quantity, q_2 , would be less than the original scenario's increased allocation of water, q_1 . However, the particular supply curve shown will depend on the local context. For example, a water-rich region will have a greater elasticity of supply. Therefore, a shift in demand would not result in the large over allocation (i.e., gap between water supply and demand) that has been observed in Texas.

¹² Produced water contains high levels of salt, hydrocarbons, and even radioactive matter. This water, if spilled onto, for example, agricultural land, would negatively impact production of many crops.

Figure 3. Schematic of Water Supply and Demand in a Water-Scarce Locale

Because market forces in Texas are impeded from setting the price of water, other regulations must be put into place to resolve the discrepancy between supply and demand. As described below, the use of brackish groundwater—if properly managed and incentivized—could offer Texas a way to both expand water supplies and reduce demand on existing fresh water sources and may offer future options for other water-scarce regions.

3.0. Other Jurisdictions

When considering policy solutions for regulating brackish groundwater in Texas, it is useful to examine the approaches taken by other jurisdictions. Brackish groundwater is withdrawn for consumptive use in other parts of the United States, including Florida, Arizona, and New Mexico. These states rely on desalination of brackish groundwater for portions of their water supply or have substantial brackish groundwater resources that may provide such supplies in the

future. Although Texas is geologically, geographically, and institutionally unique from these jurisdictions, questions regarding the management of the other states' brackish groundwater resources may offer ideas for new solutions. We provide a brief overview of the governing and permitting regimes in each state and, in particular, examine whether each provides for disparate governance of brackish and fresh groundwater.

3.1. Florida

Florida depends on desalination of brackish groundwater to augment its water supply. Desalination of brackish groundwater in Florida is expected to produce approximately 850,000 m³ per day by 2025, providing an estimated 11% of the additional estimated water demand (Division of Water Resource Management 2010). Groundwater, like all water in Florida, is considered a public resource, which the Florida Legislature has directed should be managed on a state and regional basis (Fla. Stat. §373.016[4]). The legislature has indicated its desire to encourage and facilitate the use of water resources nearest to the area or application of use, including the use of alternative water supplies, such as brackish groundwater (Fla. Stat. §§373.016; 403.0882).¹³

In order to use groundwater in Florida, a person is required to obtain a consumptive use permit. Permits for consumptive use of water may be issued for a period of 20 years if there is sufficient data to support the issuance, or they may be issued for shorter periods (Fla. Stat. §373.236[1]). However, the state offers additional flexibility in permitting requirements for alternative water supplies, including brackish groundwater. A person who wishes to develop these supplies may receive a permit for a longer term if there is sufficient data to show that permitting conditions—

¹³ The term “alternative water supplies” is defined in statute to include brackish groundwater (Fla. Stat. §373.019). Specifically, the statute provides that “alternative water supplies” means “salt water; brackish surface and groundwater; surface water captured predominately during wet-weather flows; sources made available through the addition of new storage capacity for surface or groundwater, water that has been reclaimed after one or more public supply, municipal, industrial, commercial, or agricultural uses; the downstream augmentation of water bodies with reclaimed water; stormwater; and any other water supply source that is designated as nontraditional for a water supply planning region in the applicable regional water supply plan.”

including protection of nearby or connected fresh aquifers—will be met for that term, and that term may be extended at the permittee’s request to accommodate the need to retire bonds issued for construction of the project (Fla. Stat. §373.236[5]). The legislature included language that makes it clear that the favorable conditions of this type of permit are not available for the use of non-alternative water supplies, even going so far as to single out non-brackish groundwater supplies (Fla. Stat. § 373.236[5][b][3]). Furthermore, the Florida Legislature has stated explicitly that it sees alternative water supply development projects as vital to meeting anticipated water demands in the state, and offers 50-year permits to local governments and certain utilities that contract with a private landowner “for the purpose of more efficiently pursuing alternative public water supply development projects identified in a district’s regional water supply plan and meeting water demands of both the applicant and the landowner” (Fla. Stat. § 373.236[6]). These more favorable permit conditions offer would-be developers of alternative water supplies—including brackish groundwater—greater regulatory certainty and fewer bureaucratic hurdles than they are required to clear to move their projects forward, thus facilitating the use of these supplies.

3.2. Arizona

Arizona has an estimated 740,000 MCM of brackish water (defined as water containing 1,000–10,000 mg L⁻¹ TDS) in its aquifers, mostly at depths of less than 366 m (McGavock and Collum 2008). Groundwater rights in Arizona have evolved over the years—in turn embracing the doctrine of absolute ownership, allowing near unlimited production of groundwater under the doctrine of reasonable use, and recognizing that groundwater is owned by the owner of the land above—before settling into the current state (Schaffer 2010). In 1980, Arizona adopted the Groundwater Management Code, which designated as Active Management Areas (AMAs) parts of the state where groundwater depletion was known to be a problem (Ariz. Rev. Stat. §45-411). Within the AMAs, groundwater uses are determined by historic use during the five-year period before the AMA was created—i.e., rights are “grandfathered.” There are three types of grandfathered rights, each of which is subject to different terms regarding where, how, and by whom water may be used (see Ariz. Rev. Stat. §45.461 et seq.). There are three exceptions to the “grandfathered” rule within an AMA: municipalities, private water companies, and irrigation districts may serve customers within their service areas (Ariz. Rev.

Stat. §45-491 et seq.). The code also establishes “irrigation non-expansion areas” (INAs), in which only land that was legally irrigated during a set period (or that has had significant capital investment for improvement during a specified time) in the past may continue to be irrigated (Ariz. Rev. Stat. §§45-431–45.440). Users of non-exempt wells¹⁴ in INAs must meter and report water use (Arizona Department of Water Resources 2014; Ariz. Rev. Stat. 45.437).

Outside of an AMA or INA, groundwater in Arizona is subject only to limited regulation. A person may withdraw and use groundwater for reasonable and beneficial use, subject to restrictions on transportation to certain AMAs (Ariz. Rev. Stat. §45-543). The Arizona Department of Water Resources limits the quantity of groundwater that can be produced annually, and non-exempt users are required to pay a groundwater withdrawal fee on each acre-foot of groundwater pumped (Ariz. Rev. Stat. §§45-611–45-618). One may obtain a permit for “poor quality groundwater” for a term up to 35 years for non-irrigation uses if that water cannot be used for other beneficial uses¹⁵ at the time of permit issue (Ariz. Rev. Stat. §45-516). This permit term is similar to Florida’s 30-year permit for alternative water supplies and may offer some incentive to use brackish groundwater.

3.3. New Mexico

Groundwater resources in New Mexico belong to the public (N.M. Stat. §72-12-1). They are subject to the doctrine of prior appropriation and managed by the Water Resources Allocation Program in the Office of the State Engineer. Under the state’s Groundwater Code, the state engineer obtains control over groundwater by “declaring” a groundwater basin. As of 2006, the state engineer had declared all basins in the state (Bushnell 2012). Within a declared basin, a permit is required for new groundwater appropriations, alterations to existing uses, and drilling of supplemental or replacement wells (N.M. Stat. §§72-12-1–72-12-24). Unlike Texas, New Mexico legally recognizes that groundwater and surface water are connected, which means that both groundwater and surface water rights must be considered in appropriation decisions (*Hydro Resources Corp. v. Gray*, 173 P.3d 749, 756 [N. Mex. 2007]).

¹⁴ Wells with a capacity of < 35 gallons per minute are exempt. The water must be used for non-irrigation (generally domestic) purposes and may be used to water up to two acres of grass or garden.

¹⁵ Beneficial uses in Arizona are listed as “domestic (which includes the watering of gardens and lawns not exceeding one-half acre), municipal, irrigation, stockwatering, water power, recreation, wildlife including fish, nonrecoverable water storage, and mining uses” (Ariz. Rev. Stat. §45-151[A]).

New Mexico classifies water containing not less than 1000 ppm TDS as “nonpotable water” (N.M. Stat. §72-12-25). The state classifies as a “non-potable deep aquifer” an aquifer that has clearly defined boundaries and a top depth of at least 2,500 ft (762 m) below ground and that contains nonpotable water (N.M. Stat. §72-12-25). If the state engineer declares such an aquifer to be a groundwater basin, the aquifer is then subject to regulation by the state engineer (N.M. Stat. §72-12-25). Appropriations of groundwater from a declared non-potable deep aquifer for oil and gas, prospecting, mining, road construction, agriculture, electricity generation, industry, and geothermal use are exempted from most regulations (N.M. Stat. §72-12-25[B][1]), but other uses are subject to the same regulations as fresh water (N.M. Statutes §72-12-25[B][2]). Thus, production of brackish resources for heavier industry uses, by virtue of carrying less regulation, may be more attractive for certain users.

Despite limited state regulatory incentives for brackish groundwater use, New Mexico is the site of the Brackish Groundwater National Desalination Research Facility, a research center directed by the U.S. Bureau of Reclamation that focuses on issues related to brackish groundwater desalination. The facility is located at Alamogordo in the Tularosa Basin, which possesses vast brackish groundwater resources.

In sum, our review of groundwater regulation in Florida, Arizona, and New Mexico offers a few insights into practices for governing brackish groundwater. First, none of the states examined give brackish groundwater extensive, disparate treatment. Where brackish resources were singled out, the provisions were rare and short on detail within the greater context of groundwater, generally. Second, none of the states drew clear or precise lines to identify brackish water resources for governance purposes, which speaks to the difficulty of delineating the supplies clearly. Florida lumped the term in with a greater “alternative” source, Arizona referred to “poor quality groundwater,” and New Mexico used parameters of the aquifer along with characteristics of the water to identify the resource. Each state, however, offered some type of lowered bureaucratic hurdle in authorizing the use of those resources.

4.0. Desirable Goals for Managing Brackish Groundwater

In formulating policy for brackish groundwater, it is useful to keep in mind desired objectives for stakeholders, including landowners, municipalities, agriculture, industry, and the environment. In our case study of Texas, fresh water supply is less than the increasing demand, and resources are decreasing due to drought, climate change, and overuse. Currently, brackish groundwater is both often more expensive to develop and potentially more problematic for the environment than are many sources of fresh water. However, many believe that developing brackish groundwater will help fill the gap between water supply and demand. Although, as described in Section 2.3, a functioning water market, wherein water was appropriately priced according to supply and demand, would eliminate some of the disparity between supply and demand. However, the current regulatory framework in Texas makes a statewide water market, especially for groundwater, nearly impossible.¹⁶ The political reality is that—barring catastrophic developments—Texas is unlikely to change its groundwater governance regime anytime soon. Thus, Texas must turn to regulatory incentives to facilitate brackish groundwater development.

To be successful, policy initiatives must work largely within the current structure while incentivizing actors to change the way they manage and use water. Although municipalities must desalinate the water or blend brackish water with fresh water prior to use, industries, such as oil and gas (and, in a few cases, agriculture), that are able to operate using water with higher levels of TDS may choose to use brackish groundwater if it is technically viable and makes economic sense. These users, by switching to brackish groundwater, can reduce fresh water demand without incurring a high cost, making incentives to use brackish groundwater a potentially strong water policy tool to augment water supply and ease fresh water demand in some regions.

¹⁶ Despite the obstacles, one optimistic legislator has filed a bill requiring the TWDB to study the creation of a water market in Texas, including the development of infrastructure to transport water around the state (H.B. 3298, 84th Reg. Session, 2015).

We posit that a list of objectives for good management of brackish groundwater should include—though not consist exclusively of—the following:

- (1) facilitating access to and incentivizing development of brackish groundwater supplies to increase water supply and relieve demand on fresh water aquifers suffering from over-subscription by streamlining regulatory and bureaucratic requirements and costs;
- (2) creating regulatory certainty for all stakeholders so they know the quality and quantity of their water supplies are secure;
- (3) ensuring fresh water aquifers are protected from the consequences of producing brackish groundwater withdrawn from the same or a nearby aquifer;
- (4) ensuring that brackish aquifers are protected from contamination by injection wells for waste disposal; and
- (5) respecting private property rights in accordance with applicable law.

Public policies should be constructed to facilitate achievement of these objectives. Allowing the current groundwater governance regime alone to control this new resource means a missed opportunity to facilitate the expansion of water supply; incentivize smarter, targeted water use; and enable fresh water conservation. Except for the rules in nine GCDs, current groundwater regulation in Texas does not take into account differences in water quality or the ability of brackish groundwater to alleviate stress on fresh groundwater resources. With demand likely to increase over the next decades as Texas's population grows and industries such as oil and gas increase water demand in some areas, long-term water security in the state depends on proper management of all water resources.

5.0. Previously Proposed Policies

We review here a number of policies that have been proposed to address questions surrounding brackish groundwater regulation in Texas. These proposals include ideas about how to identify or classify brackish groundwater, how to incentivize its use prior to that of fresh water where appropriate, and how to manage and protect Texas aquifers. Funding and other policy support for the advancement of desalination technology and construction of desalination facilities in order to facilitate the economic use of brackish groundwater, once produced, are key pieces of the puzzle as well, but will not be considered here.

5.1. Defining “Brackish Groundwater”

Fundamental to policy facilitating beneficial use of brackish groundwater is identifying water that constitutes brackish groundwater. The Texas Legislature began seriously considering brackish groundwater policy—including how to define the resource—during the 2013 legislative session. One early proposal was to remove groundwater $>1,000$ ppm TDS from regulation by GCDs (H.B. 2334, 83rd Reg. Session, 2013). This would essentially deregulate some groundwater currently under GCD jurisdiction, as many aquifers colloquially considered to contain fresh water have TDS levels $>1,000$ ppm. In some portions of Texas, much of the groundwater currently used is brackish under this definition (Stewart 2015). Attempts to separate out some supplies for disparate governance are seen by some locals as nothing more than a power grab or an attempt to undermine current law (Richardson 2015). This proposal failed to advance significantly in the 2013 legislative session, due in part to concerns from stakeholders regarding the difficulties of managing an unregulated resource connected so closely to other groundwater and of determining whether a resource would be regulated prior to drilling a well (Steinbach 2013).

Although brackish groundwater resources are often identified using specific TDS concentration ranges, the lower limit of the definition is subject to debate, as actors are able to use groundwater with varying levels of TDS without advanced treatment. For example, water use in the Gonzales County Underground Water Conservation District varies dramatically in terms of quality: agricultural users use water up to 3,700 ppm TDS, the City of Gonzales uses water at 2,800 ppm

TDS by blending it with fresh surface water, and oil and gas companies are using water up to 26,000 ppm TDS for hydraulic fracturing operations (Texas House Natural Resources Committee 2015). As such, stakeholders in Texas have opposed using a bright-line rule in state regulations, moving instead toward a multifactor analysis that considers scientific data such as hydrogeological connections to currently used sources, as well as governance and management regimes currently applied to the resource in question (Steinbach 2013).

Rather than define a numerical threshold or other bright-line rule to identify brackish groundwater, Texas policymakers in the 2015 Legislative Session, adopted legislation that requires the TWDB to designate “brackish water production zones” (BWPZs). To be designated as a BWPZ, an area of the state must have moderate to high availability and productivity of brackish groundwater. The area must be characterized by the presence of hydrogeological barriers that prevent interaction with surrounding fresh aquifers or fresh subsections of aquifers and may not be (1) a water source >1000 ppm TDS that is already serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones; (2) located within certain political subdivisions; or (3) designated or used for wastewater injection through the use of injection wells or disposal wells (H.B. 30, 84th Reg. Session, 2015). These criteria take advantage of more easily discernable and immutable geologic and political characteristics rather than relying solely on TDS, which may vary over time, geological coordinates, and depth.

5.2. Streamlined Permitting Requirements to Incentivize Use

Once brackish groundwater is defined in the law, policy incentives for its development and use are possible. H.B. 30, as passed, did not include language authorizing or mandating the options to facilitate or incentivize brackish groundwater use that were included in the original proposed versions of the bill, which is a missed opportunity for Texas and water stakeholders. Earlier versions of the legislation would have required GCDs to adopt rules for the management of brackish groundwater, including rules for issuing permits. As initially proposed, permits within a BWPZ would have a minimum term of 30 years, provide for unlimited production, and require “reasonable” monitoring and reporting to identify harmful impacts to the aquifer and other nearby water resources (H.B. 30, as introduced, 84th Reg. Session, 2015). Other proposed

policies for BWPZs included limiting GCDs' ability to regulate well spacing in the zones (H.B. 836, 84th Reg. Session, 2015). Long permit terms and limiting GCDs' ability to regulate pumping rates or well spacing within a BWPZ would, theoretically, provide an incentive for utilization of that resource relative to fresh water. Additionally, GCDs should perhaps consider adopting permitting rules that allow for flexibility of term length to accommodate the need to retire bonds issued for construction of water development projects, as Florida has done. BWPZs seem somewhat similar in character to New Mexico's designated non-potable deep aquifers, within which certain uses enjoy exemption from more extensive regulation. However, while intended to move water users toward brackish resources, there is no evidence that these particular increases in regulatory certainty and available water will sufficiently offset the cost of deeper wells or advanced treatment processes. This judgment is likely to vary widely case-by-case.

Some stakeholders have questioned whether establishing BWPZs significantly alters the current regulatory environment, given that GCDs already have authority under the Texas Water Code¹⁷ to adopt different rules for an aquifer, subdivision of an aquifer, or geologic strata (Texas House Natural Resources Committee 2015). In fact, several GCDs have adopted rules easing the regulatory burden on brackish groundwater production (described above), and two districts have established management zones for brackish water—the Barton Springs/Edwards Aquifer Conservation District (Saline Edwards Management Zone) and the Plumb Creek Conservation District (Brackish/Saline Edwards-Trinity Management Zone). Additionally, several GCDs use water >1,000 ppm TDS as they would fresh water with no special distinction (Stewart 2015).

In terms of facilitating access to and development of brackish groundwater, water developers may still benefit from the creation of BWPZs in the future, as future sessions may bring additional requirements for the zones. Future proposals may mandate the adoption of relaxed permitting rules or other incentivizing provisions and potentially counteract any local efforts to

¹⁷ Section 36.116(d), Texas Water Code, reads: "For better management of the groundwater resources located in a district or if a district determines that conditions in or use of an aquifer differ substantially from one geographic area of the district to another, the district may adopt different rules for: (1) each aquifer, subdivision of an aquifer, or geologic strata located in whole or in part within the boundaries of the district; or (2) each geographic area overlying an aquifer or subdivision of an aquifer located in whole or in part within the boundaries of the district."

stymie development of the resource. Delineating rules for brackish groundwater that carry incentives in these zones would help achieve the first two of our stated policy objectives: increasing brackish groundwater use and, thus, total water supply, and providing greater regulatory certainty for investors. Would-be developers of groundwater supplies have complained that the state's system is essentially 100 distinct jurisdictions, each with its own rules and bureaucratic requirements (Texas House Natural Resources Committee 2015). The designation of BWPZs statewide may eventually provide a pathway for regulatory uniformity for this type of resource. However, such standardization would undermine the principle of local control and GCDs as the state's "preferred method of groundwater management" (see Texas Water Code §36.0015) if water regulated and used previously under GCD rules becomes subject to new, less-stringent, state regulation. This scenario may be made less likely, however, by the criterion prohibiting the designation as a BWPZ of a water source with greater than 1000 ppm TDS that is already serving as a significant source of water supply for municipal, domestic, or agricultural purposes at the time of designation of the zones.

5.3. Protection of Both Fresh Groundwater Resources and Brackish Groundwater Reserves

Managing brackish resources successfully entails both protecting fresh groundwater resources from the effects of brackish water production and protecting brackish resources—as they become current or potential sources of water for beneficial use—from harmful impacts caused by other activities, such as oil and gas production. As noted in Section 2.2, conflicts have arisen between waste disposal well permittees/operators and nearby landowners over the potential impact of waste disposal wells on brackish groundwater that could be a future water source.

Various mechanisms for protecting aquifers are in existence or have been proposed as Texas debates brackish groundwater usage. The Texas Railroad Commission (RRC) currently protects fresh groundwater from saltwater or other oil and gas waste disposed of via injection wells, requiring disposal permit applicants to show that "[injection] formations are separated from freshwater formations by impervious beds which will give adequate protection to such freshwater formations" (Texas Administrative Code §3.9[2]). The commission also has casing requirements for wells to protect useable-quality water (Texas Administrative Code §3.13). It does not specifically protect brackish water formations. One of the new legislative criteria for the

formation of a BWPZ is the presence of “hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in other aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids level of 1,000 milligrams per liter or less” (H.B. 30, 84th Reg. Session, 2015). The Texas Groundwater Protection Committee, a statutory interagency committee created to coordinate action for the protection of groundwater quality in the state, has recognized the need to protect groundwater up to 10,000 ppm TDS using measures according to its current use as a human drinking water supply (Texas Groundwater Protection Committee 2015).

State recognition of brackish water as a valuable resource and consistency across state agencies will assist further resource development. Additionally, further characterization (identifying the quality and location) of brackish groundwater resources will provide more refined estimates of Texas’ brackish groundwater reserves. This knowledge, along with an understanding that groundwater with less than 35,000 ppm TDS may be more economical to desalinate than seawater,¹⁸ will assist the state’s future decisions about what quality of groundwater is worthy of protection.

5.4. Data-Collection and Monitoring

Some have proposed that desired future conditions (DFCs) should not apply to brackish groundwater (H.B. 30, as introduced, 84th Reg. Session, 2015). The DFC process is the manner in which Texas GCDs, working together in groundwater management areas, determine 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” (Texas Administrative Code §356.10[6]). Though widely critiqued, the process creates a framework for regional discussion and decisions on groundwater availability—specifically the tradeoff between conservation and resource utilization—and feeds into the state’s water planning process. Advocates of removing brackish groundwater from the

¹⁸ We note that disposal of brine produced by inland brackish groundwater desalination may be more costly than disposal of brine produced by seawater desalination. Even though it can harm aquatic life, seawater brine may be discharged into the ocean, whereas inland brackish brine may require additional treatment, dilution, or injection.

DFC process are not without reason. Brackish water in a fossil aquifer may not be replenished by rainfall; for these aquifers, DFCs cannot reflect a balance between water withdrawals and recharge. This water can only be mined. Alternatively, the DFC process may assist in the management of brackish water that is closely linked to recharging fresh groundwater. Thus, it is important to consider the source of the brackish groundwater, not only its salinity, when analyzing the resource. Given the potential interconnectedness and opacity of hydrogeological conditions, especially in uncharacterized or poorly characterized aquifers, removing a potentially important resource like brackish groundwater from the DFC analysis entirely seems hasty and perhaps unwise. Provisions in the BWPZ-approval or other processes for identifying or designating brackish resources should consider the source and recharge rates of brackish aquifers prior to authorizing the elimination of the DFC requirement.

5.5. Other Incentive Programs

In a study examining water use in the Eagle Ford Shale, Arnett et al. (2014) propose the creation of a program offering both recognition by the state and tax incentives in exchange for avoiding fresh water use in hydraulic fracturing operations. The proposed Green Star Program, administered by the RRC or TCEQ, would recognize oil and gas operators at various levels based on the amount of fresh water used (Arnett et al. 2014). For example, a company using only 30% fresh water would be awarded the lowest level of recognition. “Green star” holders could be offered severance tax reductions¹⁹ or other monetary incentives to promote investment in brackish groundwater (i.e., deeper wells) or water reuse/recycling systems. Although this program was proposed for the Eagle Ford region, such a program could be implemented statewide, providing a way to incentivize the use of brackish groundwater without undermining local governance regimes. Additionally, such a program would incentivize water reuse, in addition to brackish groundwater use, and boost an operator’s image in the community. In order to be implemented successfully, such a program would require reporting of not only the volumes of water used but also its source and quality (Arnett et al. 2014).

¹⁹ Offering severance tax reductions for reduced fresh water usage will naturally have some level of fiscal impact to the state’s coffers. One option for making the proposal “revenue neutral” would be to raise the severance tax for operators who use more than a certain amount of fresh water. As noted, reporting requirements around quantity and quality of water use would have to be tightened in order for such a system to be effective.

6.0. Conclusions and Policy Recommendations

Currently in Texas, water demand exceeds supply, a situation continually exacerbated by Texas's legal and institutional framework—including reliance on the rule of capture—which fails to fully and appropriately allocate the full costs of water to users and creates incentives for wasteful and inefficient use. Broad changes are unlikely in the current political environment, so policymakers must work within the current legal structure to incentivize Texans to change the way they manage and use water. As a well-developed state with vast brackish water resources and technological know-how, Texas is well positioned as a potential laboratory for the enactment of policies to facilitate development of this alternative resource. Although it comes with greater cost and potential environmental impacts, the use of brackish groundwater presents a number of advantages, including both alleviating the demand for and increasing the supply of fresh water. Texas should implement policies to incentivize brackish groundwater use and facilitate expansion of the water supply. The goal of this paper is not to propose an overhaul of water regulation in Texas, but rather to offer ways in which the state could work within the preexisting framework to promote diversity in the water resource base and to provide potential lessons for other regions. If Texas is successful at achieving stakeholder agreement on important issues such as defining the resource for purposes of regulation or the development of local or state incentives for its use, the state's experience may illuminate valuable options for other arid jurisdictions considering brackish groundwater use.

Water resources should be regulated and managed in a way that encourages brackish groundwater development without adversely affecting fresh water resources, creates regulatory certainty, protects potential brackish groundwater resources for the future, and respects property rights. The BWPZ proposal recently enacted by the legislature is a significant step toward goal of clearly identifying brackish groundwater resources in the law. However, the Legislature missed the opportunity to lessen regulatory requirements or offer incentives to make the use of brackish groundwater more economical where appropriate. Furthermore, legislators and agency regulators must be careful to find the proper balance between deregulation that may lead to environmental harm and restrictions that may make use of brackish groundwater economically unviable. Also

important are laws that protect both fresh water sources and brackish groundwater sources, which are likely to serve as important water resources now and in the future.

Finally, acquiring better knowledge and understanding of hydrogeological resources will allow policymakers to make better decisions about how to manage brackish groundwater resources and protect aquifers, brackish and fresh. All stakeholders, from water developers to agricultural interests, benefit from increased certainty, knowledge, and understanding of subterranean water resources. In fact, more information supports all the desired policy objectives: understanding more of the mysteries behind the “secret, occult, and concealed”²⁰ movement of groundwater and the interconnectedness of aquifers—both to other aquifers and to surface water resources—provides a firmer foundation for regulatory policy and permitting decisions. To this end, the State of Texas and other arid jurisdictions should continue to fund research and mapping efforts for aquifers—brackish and fresh—and expand modeling efforts that seek to understand the interplay between surface water and groundwater. This reduces risk for investors, improves society’s ability to protect the resources, and—where applicable—even helps to protect individual or collective rights by taking some of the guesswork out of questions about whether and how much to pump.

The State Water Plan has documented a growing disparity between Texas water supply and demand, which is caused by a rapidly increasing population, economic growth, drought, and rising calls for environmental flows. The shortage, if left unaddressed, is likely to lead, ultimately, to crisis or conflict between water users, with the attendant effects on the Texas economy and human well-being. Increased understanding and utilization of unconventional water resources will increase water security and assist economic growth into the future. Facilitating the responsible development of brackish groundwater now will help to relieve pressure on fresh water resources and may postpone or alleviate crises over water in years to come.

²⁰ *Houston & Texas. Cent. Ry. Co. v. East*, 81 S.W. 279, 281 (Tex. 1904).

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